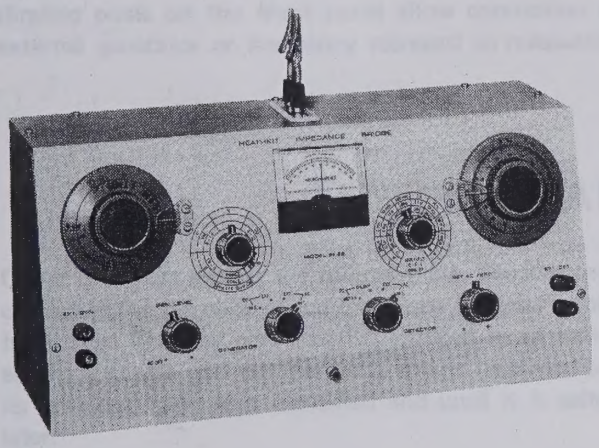
CONDENSED

Assembly and Operation of the

HEATHKIT®

IMPEDANCE BRIDGE

MODEL IB-28



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HEATH COMPANY
BENTON HARBOR, MICHIGAN 49022

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IMPEDANCE BRIDGE

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INTRODUCTION

The Heathkit Model IB-28 Impedance Bridge is a self-contained, direct-reading precision instrument for accurate and rapid measurement of resistance, capacitance, inductance, dissipation factor of capacitors, and storage factor of inductors. A 4-arm bridge, using precision components, is the heart of the instrument. It can be switched into a number of basic bridge circuits.

Bridge balance is indicated by a 100-0-100 microammeter. A suitable shunt protects the meter against accidental overload and may be switched out of the meter circuit during final balance to provide maximum null sensitivity.

A built-in, vacuum tube, phase-shift generator with a frequency range of approximately 800 to 1200 Hz is provided for measurement functions that require the use of an AC signal. An adjustable trimmer capacitor is used to set the frequency of the internal generator to exactly 1000 Hz. Binding posts on the front panel allow connection of an external generator or frequency standard so measurements can be made at a frequency other than that provided by the built-in generator.

A built-in vacuum tube amplifier and detector, in conjunction with the zero center microammeter, provides a very sensitive null indicating circuit for inductance and capacitance measurements. Front panel binding posts allow an external detecting device to be used instead of the built-in null indicating circuitry. Bridge balance is then indicated by the readout device normally used with the external detector.

The external generator binding posts and the external detector binding posts can be used when the appropriate Generator and/or Detector switch is in the AC EXT position.

Refer to the "Kit Builders Guide" for complete information on unpacking, parts identification, tools, wiring, soldering, and step-by-step assembly procedures.

PARTS LIST

Check each part against the following list. The key numbers correspond to the numbers on the "Parts Pictorial" (fold-out from Page 5). Any part that is packaged in an individual envelope with a part number on it, should be placed back in its envelope after it is identified and until it is called for later.

To order a replacement part, use the Parts Order Form furnished with this kit. If a Parts Order Form is not available, refer to "Replacement Parts" inside the rear cover of the Manual.

KEY No.	PART No.	PARTS Per Kit	DESCRIPTION	PRICE Each
RESISTORS				
1/2-Watt				
A1	1-2	2	68 Ω (blue-gray-black)	.15
A1	1-9	1	1000 Ω (brown-black-red)	.15
A1	1-44	1	2200 Ω (red-red-red)	.15
A1	1-20	1	10 kΩ (brown-black-orange)	.15
A1	1-22	1	22 kΩ (red-red-orange)	.15
A1	1-25	1	47 kΩ (yellow-violet-orange)	.15
Resistors (cont'd.)				
A1	1-26	1	100 kΩ (brown-black-yellow)	.15
A1	1-29	1	220 kΩ (red-red-yellow)	.15
A1	1-33	5	470 kΩ (yellow-violet-yellow)	.15
A1	1-34	1	680 kΩ (blue-gray-yellow)	.15
A1	1-35	4	1 MΩ (brown-black-green)	.15
A1	1-37	1	2.2 MΩ (red-red-green)	.15
A1	1-71	1	4.7 MΩ (yellow-violet-green)	.15

INTRODUCTION

The Heathkit Model 1B-28 Impedance Bridge is a self-contained, direct-reading precision instrument for accurate and rapid measurement of resistance, capacitance, dissipation factor or capacitance, and storage factor of inductors. A 4-arm bridge, using precision components, is the heart of the instrument. It can be switched into a number of basic bridge circuits.

Bridge balance is indicated by a 100-0-100 microammeter. A sensitivity shunt switch protects the meter against overload and may be switched out of the meter circuit during final balance to provide maximum null sensitivity.

A built-in, vacuum tube, phase-shift generator with a frequency range of approximately 800 to 1200 Hz is provided for measurements requiring the use of an AC signal. An adjustable damping capacitor is used to set the frequency of the internal generator to exactly 1000 Hz. Binding posts on the front panel allow connection of an external generator or frequency standard as measurements

PARTS LIST

Check each part against the following list. The key numbers correspond to the numbers on the "Parts Pictorial" (Drawing Nos. Dwg. A61, etc.) that is provided in an envelope with a part number on it. Identify each part in the pictorial and check it off in the list. Use care in identification and note if it is called for more than once.

To order a replacement part, use the Parts Order Form included with this Kit. If a Parts Order Form is not available, refer to "Replacement Parts" inside the rear cover of the Manual.

KEY PART No.	No.	PARTS Per Kit	DESCRIPTION	PRICE Each
RESISTORS				
1/2-Watt				
A1	1-2	2	68 Ω (blue-gray-black)	.15
A1	1-3	1	1000 Ω (brown-black-red)	.15
A1	1-24	1	2200 Ω (red-red-red)	.15
A1	1-20	1	10 kΩ (brown-black-orange)	.15
A1	1-22	1	20 kΩ (red-red-orange)	.15
A1	1-25	1	47 kΩ (yellow-violet-orange)	.15
A1	1-29	1	100 kΩ (brown-black-yellow)	.15
A1	1-28	1	220 kΩ (red-red-yellow)	.15
A1	1-23	1	470 kΩ (yellow-violet-yellow)	.15
A1	1-34	1	680 kΩ (blue-gray-yellow)	.15
A1	1-26	4	1 MΩ (brown-black-green)	.15
A1	1-27	1	2.2 MΩ (red-red-green)	.15
A1	1-21	1	4.7 MΩ (yellow-violet-green)	.15

KEY No.	PART No.	PARTS Per Kit	DESCRIPTION	PRICE Each
Precision				
A2	2-1	1	1 Ω	1.15
A2	2-2	1	9 Ω	1.15
A2	2-3	1	90 Ω	1.05
A2	2-4	1	100 Ω	1.05
A2	2-59	1	550 Ω	1.05
A2	2-5	2	900 Ω	1.05
A2	2-6	9	1000 Ω (1 k)	1.00
A2	2-7	2	9000 Ω (9 k)	1.00
A2	2-10	1	90 kΩ	1.05
Other Resistors				
A3	1-24-1	1	4700 Ω, 1-watt (yellow-violet-red)	.15
A3	3-5-2	1	2.2 Ω, 2-watt (red-red-gold)	.50
A4	1-13-2	2	220 Ω, 2-watt (red-red-brown)	.20
CAPACITORS				
B1	20-11	2	100 pF mica	.30
B2	20-112	1	310 pF mica	.40
B3	20-27	1	.01 μF (10,000 pF) mica	2.75
B4	20-28	1	.1 μF (100,000 pF) mica	15.95
B5	21-140	2	.001 μF disc	.15
B6	27-115	1	.005 μF Mylar*	.25
B6	27-116	6	.02 μF Mylar	.30
B7	25-206	1	20/20 μF electrolytic	1.30
B8	25-28	1	100 μF electrolytic	.90
B9	25-26	1	1000/1000 μF electrolytic	2.65
B10	31-9	1	80-400 pF trimmer	.75
CONTROLS-SWITCHES				
C1	10-262	1	10 kΩ control	1.35
C2	13-2	1	165 Ω/1600 Ω/16 kΩ, 3-section control	13.75
C3	19-36	1	1250 Ω control w/10-position switch	6.15
C4	19-127	1	10 kΩ control w/switch	2.65
C5	63-512	1	4-position spring-loaded switch	4.45
C6	63-513	1	4-position, 2-section switch	4.45
C7	63-514	1	8-position, 2-section switch	4.40
C8	63-515	1	5-position, 3-section switch	5.10

KEY No.	PART No.	PARTS Per Kit	DESCRIPTION	PRICE Each
HARDWARE				
#6 Hardware				
D1	250-9	15	6-32 x 3/8" screw	.05
D2	250-29	3	6-32 x 3/4" screw	.05
D3	250-8	13	#6 x 3/8" sheet metal screw	.05
D4	252-3	28	6-32 nut	.05
D5	254-1	26	#6 lockwasher	.05
D6	254-6	2	#6 external tooth lockwasher	.05
D7	259-1	9	#6 solder lug	.05
D8	255-15	3	#6 x 1/2" spacer	.05
Other Hardware				
D9	250-2	8	3-48 x 5/16" screw	.05
D10	252-1	8	3-48 nut	.05
D11	254-7	8	#3 lockwasher	.05
D12	250-43	3	#8 x 1/4" setscrew	.05
D13	253-9	4	#8 flat washer	.05
D14	252-7	9	Control nut	.05
D15	254-5	8	Control lockwasher	.05
D16	253-10	7	Control flat washer	.05
D17	252-73	1	Push-on nut	.05
METAL PARTS-WIRE-SLEEVING				
E1	200-528	1	Chassis	3.00
E2	203-542	1	Panel	3.60
E3	204-52	1	Mounting bracket	.30
	90-417	1	Cabinet	13.15
	340-3	1	Bare solid wire	.05/ft
	344-50	1	Black wire	.05/ft
	344-59	1	White wire	.05/ft
	344-52	1	Red wire	.05/ft
	344-54	1	Yellow wire	.05/ft
	89-23	1	Line cord	1.25
	346-1	1	Sleeving	.10/ft
TERMINAL STRIPS-RECTIFIERS-DIODES				
E4	431-1	3	1-lug terminal strip	.15
E5	431-2	2	2-lug terminal strip	.15
E6	431-51	1	2-lug vertical-mount terminal strip	.15
E7	431-5	4	4-lug terminal strip	.15
E8	56-26	1	1N191 germanium diode (brown-white-brown)	.40
E8	57-27	1	1N2071 silicon diode	.75
E8	57-65	4	1N4002 silicon diode	.30

*DuPont Registered Trademark

KEY No.	PART No.	PARTS Per Kit	DESCRIPTION	PRICE Each
Potentiometers				
A2	2-1	1	1 Ω	1.15
A2	2-2	1	5 Ω	1.15
A2	2-5	1	50 Ω	1.05
A2	2-4	1	100 Ω	1.05
A2	2-50	1	500 Ω	1.05
A2	2-6	2	5000 Ω	1.05
A2	2-8	6	10000 Ω (10 k)	1.00
A2	2-7	2	50000 Ω (50 k)	1.00
A2	2-10	1	80 kΩ	1.05
Other Resistors				
A2	1-24-1	1	4700 Ω, 1 watt (yellow-violet-red)	.15
A2	1-5-1	1	2.2 Ω, 2 watt (red-red-gold)	.05
A4	1-12-2	2	220 Ω, 5 watt (red-red-brown)	.20
CAPACITORS				
B1	20-11	2	100 µF mica	.20
B2	20-112	1	310 µF mica	.60
B3	20-27	1	.01 µF (10,000 pF) mica	2.75
B4	20-29	1	.1 µF (100,000 pF) mica	12.95
B5	21-140	2	.001 µF disc	.15
B6	21-115	1	.005 µF disc	.20
B7	21-110	4	.01 µF disc	.20
B7	20-206	1	.01/.01 µF mica pk.	1.20
B8	20-28	1	.05 µF electrolytic	.20
B9	20-30	1	.1/.05/.05/.05 µF electrolytic	2.95
B10	21-9	1	.25/.25/.25 µF ceramic	.75
CONTROLS/SWITCHES				
C1	10-262	1	10 kΩ control	1.25
C2	18-3	1	100 Ω (1/10 W) 1% MF resistor, 2 position control	12.75
C3	18-28	1	1,250 Ω control w/10-position switch	6.15
C4	18-127	1	10 kΩ control w/resistor	2.95
C5	23-312	1	4-position spring loaded switch	2.50
C6	23-313	1	4-position, 2 section switch	4.45
C7	23-314	1	8-position, 2-section switch	4.40
C8	23-315	1	3-position, 3-section switch	3.10

KEY No.	PART No.	PARTS Per Kit	DESCRIPTION	PRICE Each
HARDWARE				
H1	Hardware			
H1	280-8	16	6-32 x 3/8" screw	.05
H1	280-23	3	6-32 x 3/4" screw	.05
H1	280-8	12	#8 x 3/8" sheet metal screw	.05
H1	282-2	26	6-32 nut	.05
H1	284-1	26	#8 lock washer	.05
H1	284-3	2	#8 external tooth lockwasher	.05
H1	288-1	9	#8 solder lug	.05
H1	288-15	2	#8 x 1/2" spacer	.05
H1	Other Hardware			
H1	280-2	8	2-48 x 5/16" screw	.05
H1	282-1	8	2-48 nut	.05
H1	284-2	8	#2 lock washer	.05
H1	280-63	2	#2 x 1/4" screw	.05
H1	282-9	4	#2 nut, washer	.05
H1	282-7	8	Control nut	.05
H1	284-6	8	Control lock washer	.05
H1	282-10	7	Control flat washer	.05
H1	282-78	1	Push-on nut	.05
METAL PARTS-WIRE-SLEEVING				
F1	300-329	1	Chassis	2.00
C2	320-663	1	Panel	3.50
Z1	304-52	1	Mounting bracket	.20
	80-177	1	Cabinet	13.15
	340-3	1	Bare solid wire	.05/ft
	344-50	1	Black wire	.05/ft
	344-56	1	White wire	.05/ft
	344-52	1	Red wire	.05/ft
	344-54	1	Yellow wire	.05/ft
	40-22	1	Tone rod	1.25
	340-1	1	Sleeving	.10/ft
TERMINAL STRIPS-RECTIFIERS-DIODES				
E4	421-1	3	1-lug terminal strip	.15
E6	421-2	12	2-lug terminal strip	.15
E6	421-21	1	2-lug vertical mount terminal strip	.15
E7	421-6	4	4-lug terminal strip	.15
E9	56-36	1	1N1091 germanium diode	.40
			(brown-white-brown)	
E8	61-23	1	1N3071 silicon diode	.75
E8	57-65	4	1N4002 silicon diode	.20

HEATHKIT

KEY No.	PART No.	PARTS Per Kit	DESCRIPTION	PRICE Each
DIALS-KNOBS-INSERTS-SOCKETS				
F1	462-283	1	D-Q dial	3.40
F2	462-284	1	C-R-L control dial	5.00
F3	462-285	1	C-R-L switch dial	5.00
F4	463-5	2	Dial pointer	1.95
F5	462-245	6	Knob	.40
F6	455-50	6	Knob insert	.15
F7	434-15	4	7-pin socket	.20
MISCELLANEOUS				
F8	427-3	6	Binding post base	.15
F9	75-17	8	Binding post insulator	.15
F10	100-16-2	3	Black binding post cap	.15
F10	100-16-18	3	Red binding post cap	.15
F11	438-14	2	Banana plug with clip	.60
F12	261-1	4	Rubber foot	.05
F13	481-1	1	Capacitor mounting wafer	.15
F14	412-24	1	Neon lamp assembly	1.80
F15	75-71	1	Strain relief (for flat cord)	.15
F16	75-30	1	Strain relief (for round cord)	.15
F17	75-6	1	Terminal board insulator	.60
	421-26	1	Fuse (3AG, 1/8-A, slow-blow)	.50
F18	422-1	1	Fuse block	.40
F19	490-5	1	Nut starter	.15

KEY No.	PART No.	PARTS Per Kit	DESCRIPTION	PRICE Each
Miscellaneous (cont'd.)				
	51-16	1	Bridge transformer	8.50
	54-56-24	1	Power transformer	5.00
	407-4	1	Meter	16.15
	411-56	2	1U4 tube	2.40
	411-57	2	1L4 tube	4.05
	390-362	1	Fuse label	.15
	391-34	1	Blue and white identification label	
	597-308	1	Kit Builders Guide	
	597-260	1	Parts Order Form	
		1	Manual (See front cover for part number.)	2.00
	331-8		Solder (Additional 3" rolls of solder, #331-6, can be ordered for 25 cents each.)	

The above prices apply only on purchases from the Heath Company where shipment is to a U.S.A. destination. Add 10% (minimum 25 cents) to the price when ordering (Michigan residents add 4% sales tax) to cover insurance, postage, and handling. Outside the U.S.A., parts and service are available from your local Heathkit source and will reflect additional transportation, taxes, duties, and rates of exchange.

120 Volt Wiring

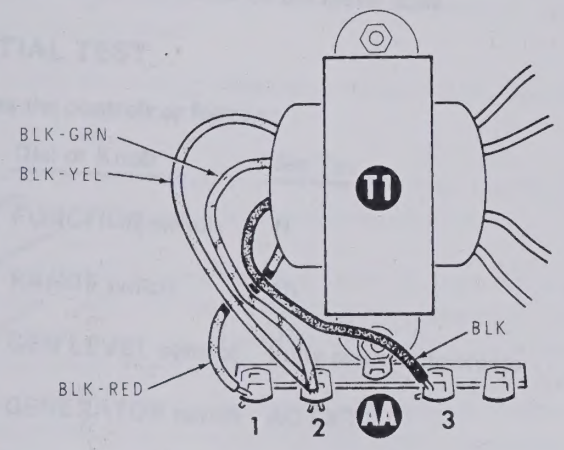
Refer to Pictorial 2 (fold-out from Page 11) and connect the primary leads of transformer T1 to terminal strip AA as follows. Be sure you make mechanically secure connections.

( ) Black-red to lug 1 (NS).

( ) Black-yellow to lug 1 (NS).

( ) Black-green to lug 3 (NS).

( ) Black to lug 3 (NS).



Detail 2A

240 Volt Wiring

Refer to Detail 2A and connect the primary leads of transformer T1 to terminal strip AA as follows. Be sure you make mechanically secure connections.

( ) Black-red to lug 1 (NS).

( ) Black-yellow to lug 2 (NS).

( ) Black-green to lug 2 (S-2).

( ) Black to lug 3 (NS).

Component Wiring

Refer to Pictorial 2 (fold-out from Page 11) for the following steps. Position the wires as shown in the Pictorial.

( ) Connect the short red transformer lead to lug 2 of terminal strip AC (NS).

( ) Connect the long red lead to lug 1 of terminal strip AJ (NS).

( ) Loosely twist together the orange leads coming from transformer T1.

( ) Connect one orange lead to lug 2 (NS) and the other orange lead to lug 3 (NS) of terminal strip AH.

( ) Press the orange and the red leads down against the chassis.

NOTE: Use the white insulated hookup wire when wire is called for in the following steps. Cut the wire to the proper length and remove 1/4" of insulation from each end unless directed otherwise in a step. Position each wire as shown in the Pictorial.

( ) Connect a 6-3/4" wire from lug 5 of switch AE (S-1) to lug 2 of fuse block AG (S-1).

( ) Connect a 16" wire from lug 7 of socket V2 (S-1) to lug 2 of capacitor AX (NS).

( ) Remove 1/4" of insulation from one end and 1" of insulation from the other end of a 3-1/2" wire.

NOTE: When a wire passes through a connection and then goes to another point, as in the next step, it will count as two wires in the solder instructions (S-2), one entering and one leaving the connection. Be sure these "through wires" are properly soldered to the connection.

( ) Insert the longer bare end of the 3-1/2" wire through lug 5 (S-2) to lug 1 (S-1) of socket V2. Connect the other end of the wire to lug 7 of socket V1 (S-1).

( ) Remove 1/4" of insulation from one end and 1" of insulation from the other end of a 5-1/2" wire.

( ) Insert the longer bare end of the 5-1/2" wire through lug 1 (NS) to lug 5 (NS) of socket V1. Connect the other end of the wire to lug 1 of control AE (S-1).

( ) Connect a 4" wire from lug 2 of terminal strip AD (NS) to lug 3 of socket V2 (NS).

( ) Connect a 4" wire from lug 1 of socket V1 (NS) to the solder lug at AJ (NS).

TEST AND ADJUSTMENT

CAUTION: Both the case and circuit ground of the Impedance Bridge are connected to the power line ground through the green lead of the line cord. When the Impedance Bridge is used in conjunction with a device such as an oscilloscope or other external instrument, the black EXT DET binding post (BG2) on the Impedance Bridge should always be connected to the chassis (ground) of the external instrument.

Refer to Figure 1 (fold-out from Page 33) for the following step.

( ) Check the position of the meter pointer. If necessary, use a small screwdriver and slowly turn the adjustment screw in the front of the meter and adjust the pointer to zero at the center of the meter scale.

INITIAL TEST

Preset the controls as follows:

Dial or Knob	Set To:
( ) FUNCTION switch	R
( ) RANGE switch	1h
( ) GEN LEVEL control	Fully counterclockwise
( ) GENERATOR switch	AC EXT.
( ) DETECTOR switch	AC EXT.
( ) SET AC ZERO control	Fully counterclockwise

NOTE: If you do not obtain the results specified in the following steps, refer to the "In Case of Difficulty" section and the "Troubleshooting Charts" in this Manual before you proceed with the adjustments.

( ) Insert the line cord plug into a suitable 50/60 Hz power outlet and turn the GEN LEVEL control just until the switch clicks on. The panel lamp should light.

( ) Turn the GENERATOR switch; then the DETECTOR switch to their AC INT positions. The meter pointer should move to left full scale.

( ) Adjustment of either the GEN LEVEL or the SET AC ZERO controls should now cause the meter pointer to move across the scale to the right.

Turn off the Impedance Bridge. This completes the "Initial Tests."

ADJUSTMENTS

The oscillator circuit is designed to operate between 800 and 1200 Hz. A trimmer capacitor is provided so the oscillator frequency can be set to 1000 Hz. Use either an audio generator and an oscilloscope, or an audio generator and headphones. Both methods are described below. Use only one of the methods.

Generator and Oscilloscope Method

Set the Impedance Bridge controls and switches as directed in the following steps. NOTE: Disregard the D-Q and C-R-L dial positions.

( ) FUNCTION switch to R.

( ) RANGE switch to 1h.

( ) GENERATOR switch to AC INT.

( ) DETECTOR switch to AC EXT.

( ) SET AC ZERO control fully counterclockwise.

( ) Set the audio generator to 1000 Hz and connect its output cable to one pair of deflection plates of the oscilloscope.

( ) Connect the terminals on the top of the Impedance Bridge to the other pair of oscilloscope deflection plates.

( ) Turn on the Impedance Bridge. Rotate the GEN LEVEL control to its fully clockwise position.

NOTE: Refer to Figure 2 (fold-out from Page 33) for the location of trimmer capacitor C2.

( ) Use a small screwdriver and, from the top of the chassis, turn the screw in trimmer capacitor C2 clockwise as far as it will go. Then turn the screw counterclockwise 3/4 of a turn.

( ) Adjust trimmer capacitor C2 until a circle or ellipse appears on the oscilloscope screen.

The frequency of the oscillator in the Impedance Bridge is now equal to the frequency of the audio generator. Turn the GEN LEVEL control fully counterclockwise to turn off the Impedance Bridge. Then proceed to "C-R-L Dial Adjustment" on Page 29.

Generator and Headphone Method

Set the Impedance Bridge controls and switches as directed in the following steps. NOTE: Disregard the D-Q and C-R-L dial positions.

( ) FUNCTION switch to R.

( ) RANGE switch to 1h.

( ) GENERATOR switch to AC INT.

( ) DETECTOR switch to AC EXT.

( ) SET AC ZERO control fully counterclockwise.

( ) Set the audio generator to 1000 Hz. Then connect its output cable to the terminals on the top of the Impedance Bridge.

( ) Connect the headphone leads to the EXT DET binding posts on the front panel.

( ) Turn on the Impedance Bridge. Rotate the GEN LEVEL control to its fully clockwise position.

( ) Use a small screwdriver and, from the top of the chassis, turn the screw in trimmer capacitor C2 clockwise as far as it will go. Then turn the screw counterclockwise 3/4 of a turn. You should now hear the 1000 Hz signal from the audio generator and a slightly higher tone signal from the impedance bridge. These signals combine to produce a throbbing tone in the headphones.

NOTE: As the adjustment of the trimmer capacitor approaches the null point in the following step, the beat of the throbbing tone you hear will become slower and slower and finally disappear. This null point is quite critical. Therefore, you may have to perform the adjustment several times. When the capacitor is properly adjusted only a single steady 1000 Hz tone will be heard.

( ) Very slowly turn the trimmer capacitor screw clockwise until a null point is reached where only a single steady tone is heard. CAUTION: If you "overshoot" the null point, turn the screw counterclockwise; then turn it clockwise again to obtain the proper null adjustment.

The frequency of the oscillator in the Impedance Bridge is now equal to the frequency of the audio generator. Turn the GEN LEVEL control fully counterclockwise to turn off the Impedance Bridge. Then proceed to "C-R-L Dial Adjustment."

C-R-L Dial Adjustment

Refer to Figure 1 (fold-out from Page 33) for the following steps.

Set the controls and switches as follows:

( ) FUNCTION switch to R.

( ) GENERATOR switch to DC INT.

( ) DETECTOR switch to DC SHUNT.

( ) RANGE switch to 100 Ω on the "R" scale.

( ) C-R-L switch dial to 5.

( ) Insert banana-plugs-with-clips in the red and black binding posts on the top of the impedance bridge. Then locate the previously set aside 550 Ω, precision resistor and connect it between the clips in the binding posts.

( ) Turn the C-R-L control dial fully counterclockwise and turn on the Impedance Bridge with the GEN LEVEL control. The meter pointer should remain at or slightly to the left of 0 at the center of the meter scale.

NOTE: The DETECTOR switch is "spring-loaded" in its METER position. This means that you must turn and hold the knob counterclockwise to obtain a reading in the METER position. The switch will return to the DC SHUNT position when the knob is released.

( ) Turn the DETECTOR switch to the DC METER position and note that the meter pointer will move full scale to the left. The pointer will return to or near zero when the knob is released.

( ) Rapidly turn the DETECTOR switch knob back and forth between the DC METER and DC SHUNT positions. At the same time, turn the C-R-L control dial clockwise until there is no change in meter reading with switch rotation.

( ) Hold the C-R-L control dial so it cannot move and loosen the dial setscrew. Now carefully turn the dial until .5 on its scale is in line with the mark on the C-R-L dial pointer. The C-R-L dials should now read 5.5.

( ) Carefully tighten the dial setscrew and again check to be sure there is no change in meter reading when the DETECTOR switch knob is rotated back and forth between the DC METER and DC SHUNT positions. Repeat this adjustment until no change in meter reading occurs.

( ) Turn the GENERATOR and DETECTOR switches to their AC EXT positions and remove the 550 Ω, precision resistor from the clips in the binding posts.

( ) Turn the GEN LEVEL control fully counterclockwise to turn off the Impedance Bridge.

The C-R-L dials are now set properly and ready for use.

CALIBRATING D-Q DIAL

NOTE: Perform the following steps only if you desire D-Q dial accuracy greater than that obtained by previously setting the mark on the Q/D-Q dial scale to the mark on the D-Q dial pointer.

Refer to Figure 3 for the following steps.

( ) Unplug the line cord from the power outlet.

( ) Unsolder the control end of the bare wire connected between lug 12 on wafer 3 of switch BE and lug 2 of control BF. Then carefully bend the bare wire away from the control lug.

( ) Temporarily connect a jumper wire or clip lead from lug 2 of control BF to terminal 2 (red binding post) on the top of the impedance bridge.

( ) Connect another jumper wire or clip lead from lug 3 of control BF to binding post 1 (black) on the top of the impedance bridge.

Set the dials and control knobs as follows:

( ) D-Q dial to 3 of the D-Q scale.

( ) C-R-L switch dial to 4.

( ) C-R-L control dial to .8 on the scale.

( ) FUNCTION switch to R.

( ) RANGE switch to 1 kΩ.

( ) GENERATOR switch to DC INT.

( ) DETECTOR switch to DC SHUNT.

( ) Turn the GEN LEVEL control clockwise to turn on the Impedance Bridge.

( ) Turn the DETECTOR switch knob to the DC METER position. The meter should read between 0 and 40 microamperes. NOTE: This reading may be to the right or to the left of the meter's zero center.

( ) Hold the DETECTOR switch knob in the DC METER position and at the same time adjust the D-Q control knob until the bridge is balanced (meter pointer to zero at center of scale). This should occur near the 20 mark on the Q scale of the D-Q dial.

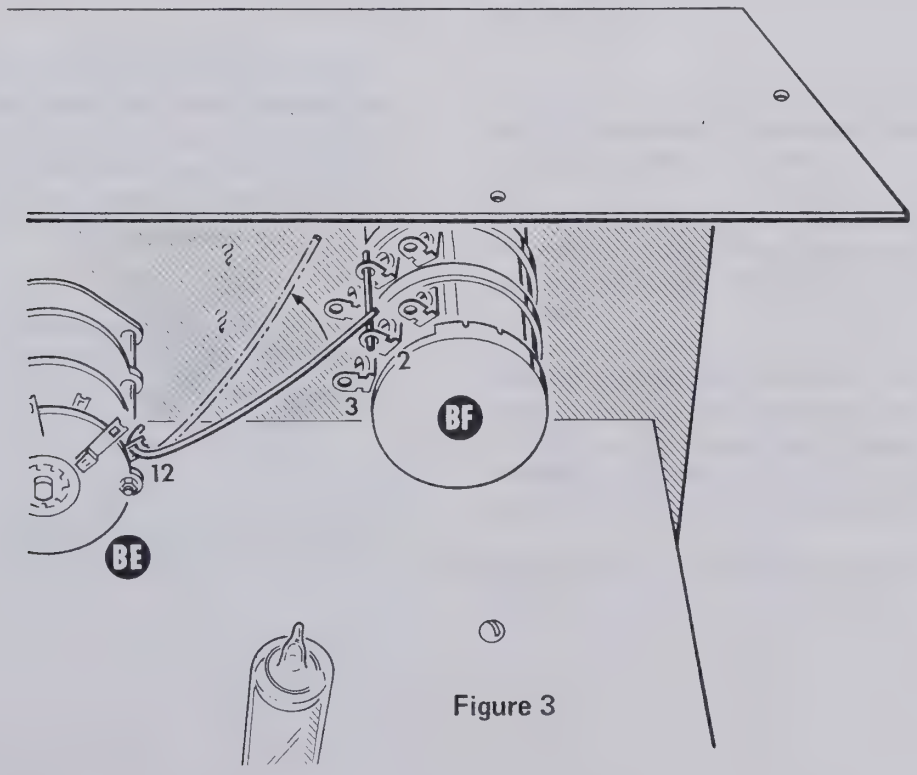


Figure 3

NOTE: The following adjustment is quite critical, therefore the procedure may have to be performed serveral times to obtain the proper null.

( ) Rapidly turn the DETECTOR switch knob back and forth between the DC METER and DC SHUNT positions. At the same time, adjust the D-Q dial until there is no change in meter reading with switch rotation.

( ) Hold the dial so it cannot move and loosen the setscrew. Now carefully turn the dial until 3 of the D-Q scale is in line with the mark on the dial pointer.

( ) Carefully tighten the dial setscrew and again check to be sure there is no change in meter reading when the DETECTOR switch knob is rotated back and forth between the DC METER and DC SHUNT positions. Repeat this procedure until no change in meter reading occurs with the D-Q dial set at 3 on the D-Q scale.

Check the D-Q dial calibration by performing the following steps.

( ) Set the D-Q dial to 8 on the D-Q scale.

( ) Turn the Range switch to the 10 kΩ position.

( ) Turn the C-R-L switch dial to 1.

( ) Hold the DETECTOR switch in the DC METER position and at the same time adjust the C-R-L control dial until the meter reads zero.

( ) The C-R-L dials should read 1.28 ± one scale division (.01) on the C-R-L control dial scale.

( ) Tighten the setscrew in the D-Q dial and unplug the power cord.

( ) Remove both of the jumper wires or clip leads connected between control BF and the binding posts on the top of the bridge.

( ) Solder the previously disconnected bare wire to lug 2 of control BF (S-1).

This completes the adjustments of your Impedance Bridge. Proceed with the "Final Assembly" steps.

FINAL ASSEMBLY

Refer to Pictorial 13 (fold-out from Page 33) for the following steps.

NOTE: The blue and white identification label, that will be installed in the next step, shows the model number and production series number of your kit. Refer to these numbers in any communications you have with the Heath Company about this kit. This assures you that you will receive the most up-to-date information in return.

( ) Carefully peel the backing paper from the blue and white identification label and position the label on the chassis as shown. Place the backing paper over the label; then firmly press the label onto the chassis.

( ) Remove the backing paper from the fuse label. Then press the label on the chassis as shown in the Pictorial. Mark the fuse type and rating on the label.

( ) Refer to the inset drawing on the Pictorial. Then, from the outside, install rubber feet in the four holes in the cabinet bottom.

( ) Insert the line cord plug through the cutout in the back of the cabinet. Then carefully mount the chassis and panel assembly in the cabinet.

( ) Be sure the line cord is not pinched between the cabinet and chassis. Then secure the cabinet to the back of the chassis with two #6 x 3/8" sheet metal screws.

( ) Line up the holes in the cabinet with the matching holes in the panel and secure the panel to the cabinet with #6 x 3/8" sheet metal screws at the seven indicated locations. CAUTION: Be careful so the screwdriver does not slip and scratch the panel.

This completes the assembly of your Impedance Bridge.

OPERATION

Make all Impedance Bridge measurements with the leads or connections of the unknown disconnected from all associated circuitry.

CAUTION: Both the case and circuit ground of the Impedance Bridge are connected to the power line ground through the green lead of the line cord. When the unknown is mounted in an external device, always connect the black EXT DET binding post on the Bridge to the chassis of the external device.

Low resistance measurements are subject to error due to the internal resistance of the bridge and the resistance of the contacts and leads. The internal resistance of the bridge can be measured by shorting the unknown binding posts with a piece of heavy wire and balancing the bridge in the normal manner. The internal resistance will probably be in the order 0.02 Ω. Lead resistance can be minimized by connecting the resistance to be measured directly between the binding posts. Cleaning the leads will also help to minimize errors due to lead resistance. When measuring low values of resistance, the internal resistance of the bridge should be determined and then subtracted from the measured value.

DC RESISTANCE MEASUREMENTS

Refer to Figure 1 (fold-out from Page 33) for the following steps.

1. Check the position of the meter pointer. If necessary, adjust the meter screw until the pointer indicates exactly zero.

2. Connect the unknown resistance between the binding posts on the top of the bridge.

3. Set the FUNCTION switch to R.

4. Set the GENERATOR switch to DC INT.

5. Set the DETECTOR switch to DC SHUNT.

6. Set both C-R-L dials to 0.

7. Plug in the line cord and turn on the Impedance Bridge.

8. Turn the RANGE switch to the position that results in minimum deflection of the meter pointer. NOTE: Choose a switch position that will give a reading to the left of the zero mark at the center of the scale.

9. Turn the C-R-L switch (outer) dial until approximate balance is obtained. Then adjust the C-R-L control (inner) dial for further balance.

10. To obtain final balance, rapidly turn the DETECTOR switch knob back and forth between the DC SHUNT and DC METER positions and, at the same time, adjust the C-R-L control dial until there is no change in the meter reading with switch rotation.

11. Multiply the readings of the C-R-L dials by the reading of the RANGE switch to determine the value of the unknown resistance. For resistance measurements below 1 Ω, it is recommended that an external galvanometer with a greater sensitivity be used.

External batteries as specified in the following chart may be used to obtain greater indicating accuracy of DC resistance measurements. CAUTION: WHEN EXTERNAL BATTERIES ARE USED, THE C-R-L SWITCH DIAL MUST NOT BE TURNED BELOW "1".

RANGE switch position:	Maximum of:	In series with:
0.1 Ω, 1.0 Ω, 10 Ω, 100 Ω	67-1/2 volts	Not less than 1500 Ω
1 kΩ	135 volts	Not less than 4000 Ω
10 kΩ, 100 kΩ, 1 MEG	202-1/2 volts	Not less than 6500 Ω

INDUCTANCE MEASUREMENTS AT 1000 Hz

NOTE: When the GENERATOR switch is in the AC INT position, inductance measurements are made using 1000 Hz, which is the frequency of the generator in the bridge. Inductance measurements may be made at other frequencies by connecting an external generator to the EXT GEN binding posts and placing the GENERATOR switch in the AC EXT position.

1. Connect the unknown inductor to the binding posts on the top of the bridge.

2. Set the GENERATOR switch to AC EXT.

3. Set the DETECTOR switch to AC INT.

4. Set the FUNCTION switch to L/DQ.

5. Set the D-Q dial to 5 on the D-Q scale.

6. Set the C-R-L switch dial to 1 and the C-R-L control dial to .5.

7. Turn the GEN LEVEL control clockwise just enough to turn the bridge on.

NOTE: In the next step, the SET AC ZERO control will be adjusted to set the meter pointer to a reading of 100 μA. This will be the point to which the bridge will be balanced in the remaining steps.

8. Adjust the SET AC ZERO control so the meter pointer indicates 100 μA at the left end of the meter scale. NOTE: DO NOT CHANGE the setting of this control throughout the following adjustments.

NOTE: Disregard the next step if an external generator is being used.

9. Set the GENERATOR switch to AC INT.

10. Adjust the GEN LEVEL control until the meter reads approximately half-scale.

11. Turn the RANGE switch to the position that will produce the greatest deflection of the meter pointer toward the left end of the scale.

12. Simultaneously adjust the D-Q dial and the C-R-L dials until the meter pointer moves toward the 100 μA balance point at the left end of the scale. Adjust the GEN LEVEL control clockwise as balance is approached so that at final balance the control will be turned fully clockwise. NOTE: If when balance is approached the D-Q dial setting is above 10 on the D-Q scale, set the FUNCTION switch to L/Q and perform the adjustments in steps 8 through 12.

13. Multiply the reading of the C-R-L dials by the L-scale reading of the RANGE switch to determine the value of the inductance (L). Read the value of Q directly from the Q or D-Q scales on the D-Q dial.

CAPACITANCE MEASUREMENTS AT 1000 HZ

NOTE: When the GENERATOR switch is in the AC INT position, capacitance measurements are made using 1000 Hz, which is the frequency of the bridge generator. Capacitance measurements may be made at other frequencies by connecting an external generator to the EXT GEN binding posts and placing the GENERATOR switch in the AC EXT position. In this case, disregard step 2 as you perform the following measurement procedure.

1. Connect the unknown capacitance to the binding posts on top of the bridge.

2. Set the GENERATOR switch to AC INT.

3. Set the DETECTOR switch to AC INT.

4. Set the FUNCTION switch to C/DQ.

5. Set the D-Q dial to zero on the DQ scale.

6. Set the C-R-L switch dial to 1 and the C-R-L control dial to .5.

7. Turn the GEN LEVEL control clockwise just enough to turn the bridge on.

NOTE: In the next step, you will adjust the SET AC ZERO control to set the meter pointer to a reading of 100 μA. This will be the point to which the bridge will be balanced.

8. Adjust the SET AC ZERO control so the meter pointer indicates 100 μA at the left end of the meter scale. NOTE: DO NOT change the setting of this control throughout the following steps.

9. Adjust the GEN LEVEL control until the meter reads approximately half-scale.

10. Turn the RANGE switch to the position that will produce the greatest deflection of the meter pointer toward the left end of the scale.

11. Simultaneously adjust the D-Q dial and the C-R-L dials until the meter pointer moves toward the 100 μA balance point at the left end of the scale. Also adjust the GEN LEVEL control clockwise as balance is approached so that at final balance, the control will be turned fully clockwise.

NOTE: If the D-Q dial setting will be below 1 on the D-Q scale when balance is obtained, set the FUNCTION switch to C/D and again perform steps 8 through 12.

12. Multiply the reading of the C-R-L dials by the C-scale reading of the RANGE switch to determine the value of capacitance (C).

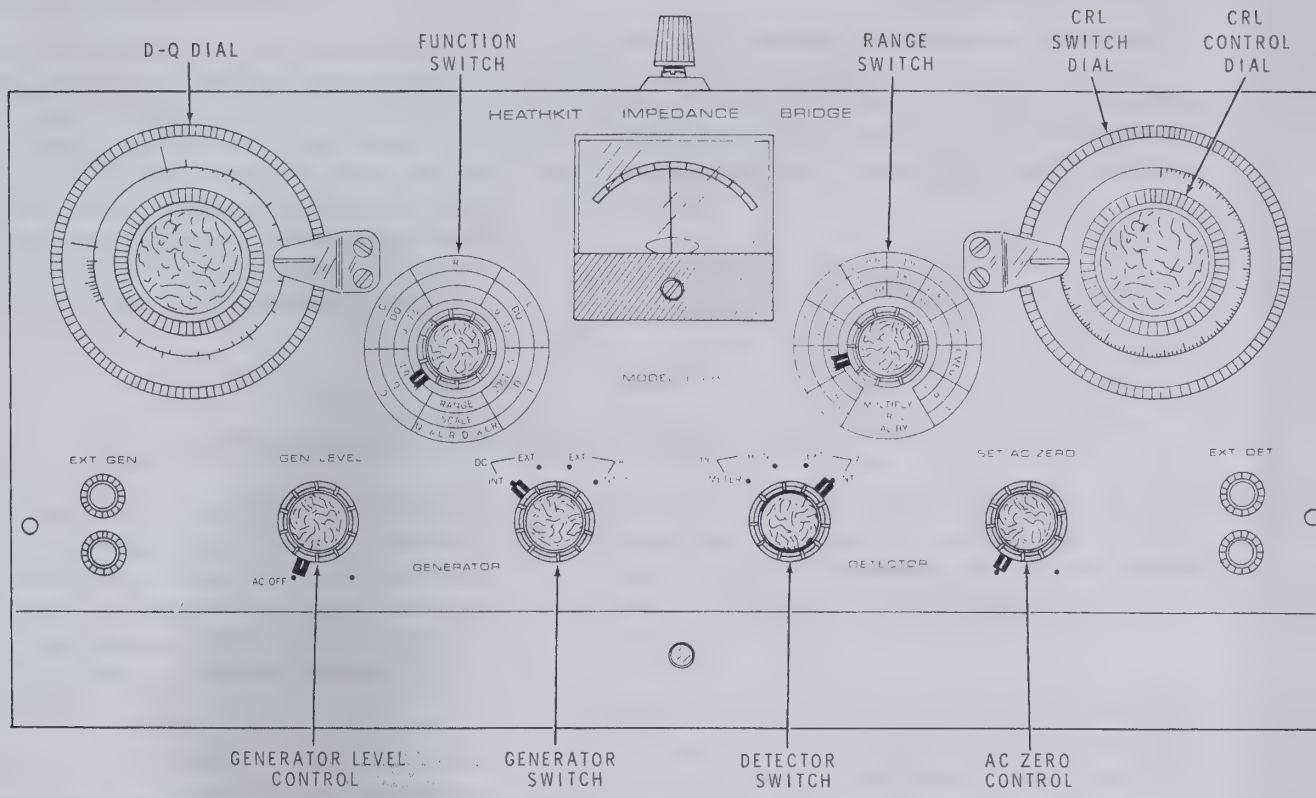


Figure 1

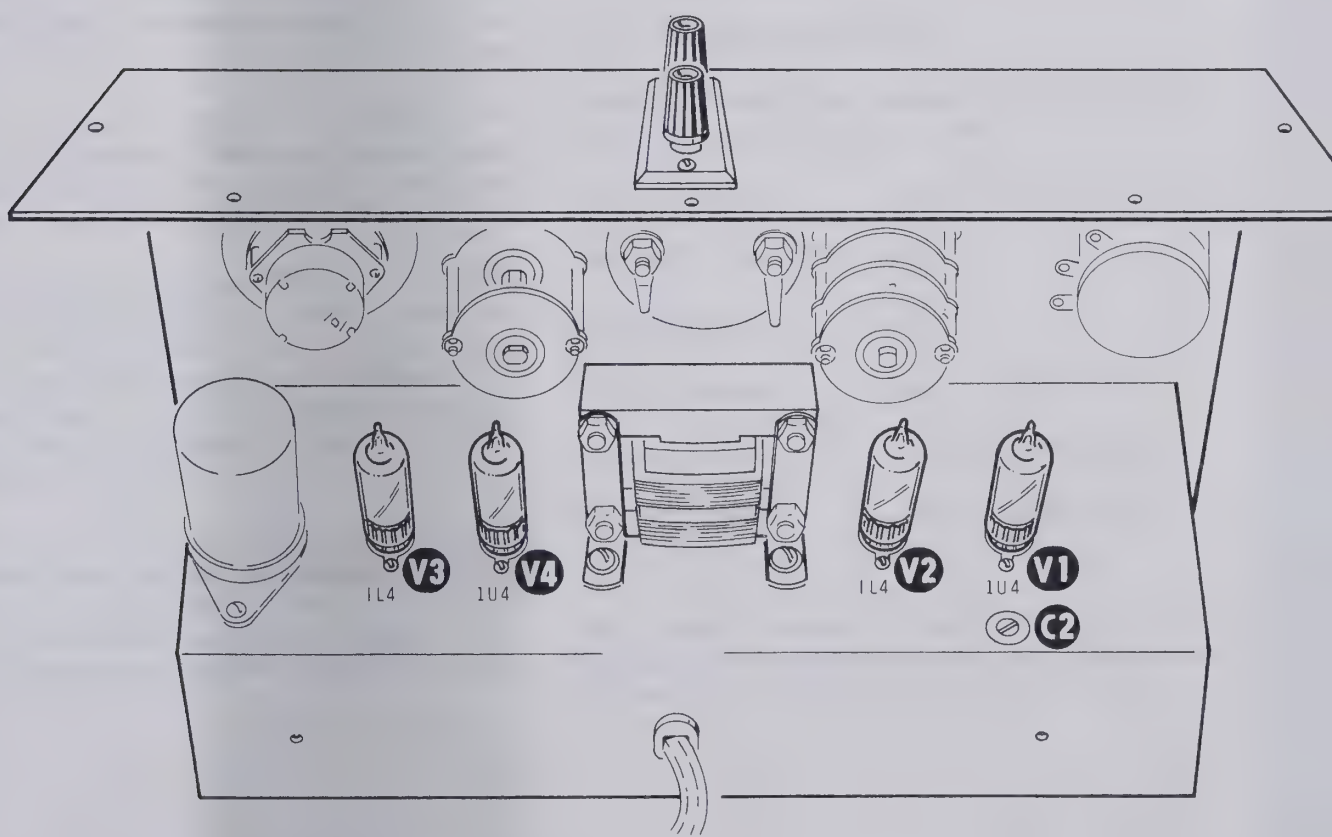


Figure 2

Dissipation factor D and storage factor Q are both frequency dependent. For a frequency of 1 kHz (the internal generator frequency), the dissipation factor and storage factor are direct reading on both the Q and D-Q dial scales. For a frequency other than 1 kHz, a correction factor must be applied to the dial reading obtained. Using an external generator at a frequency other than 1 kHz, the corrected dissipation factor D will be the value of the dial reading obtained at balance, multiplied by the frequency in kHz.

Under the same frequency condition and using the D-Q scale, the corrected storage factor Q will be the value of the dial reading at balance multiplied by the frequency in kHz. Using the Q scale, the corrected storage factor Q will be the value of the dial reading at balance divided by the frequency in kHz.

IN CASE OF DIFFICULTY

The following paragraphs deal with difficulties that might occur during the "Tests and Adjustments" and which must be corrected before the kit can be placed in normal operation. This type of difficulty is usually due to an assembly error or to an improperly soldered connection. The following checks should help you locate an error of this type if one has been made.

1. Make a careful visual check of the complete unit for any obvious error that may have been made, such as improperly soldered connections, wiring errors, bare wires touching each other, etc. Look for bits of solder, pieces of wire, or other foreign matter lodged in the wiring or components that could cause trouble. Carefully check all points where several connections are made to make sure all wires are properly soldered.

2. Make sure each wire or lead is connected to the proper place. It is quite helpful to have another person check your work. Someone familiar with the unit will often notice an error that you have overlooked.

3. Carefully check all solder connections. About 90% of the kits that are returned to Heath Company for service operate improperly due to poor solder connections. Reheat questionable connections and, if necessary, apply a little more solder to make sure connections are soldered as described in the "Soldering" section of the "Kit Builders Guide."

4. Check the values of the parts. Be sure the proper parts have been wired into each circuit as shown in the Pictorials. It would be easy, for example, to install a 1000 Ω (brown-black-red) resistor where a 10 kΩ (brown-black-orange) resistor should have been installed.

5. Check the voltages between the lugs of the tube sockets and the chassis. These voltages should be within ±10% of the values listed in the "Voltage Chart" and indicated on the Schematic (fold-out from Page 45).

In an extreme case where you are unable to resolve a difficulty, refer to the "Customer Service" information inside the rear cover of the Manual. Your Warranty is located inside the front cover.

VOLTAGE MEASUREMENTS

Preset the controls and switches as follows before you take the readings listed in the following chart.

Control or Switch:	Set to:
GENERATOR switch	AC INT
DETECTOR switch	AC INT
FUNCTION switch	Full clockwise rotation
RANGE switch	Full clockwise rotation
GEN LEVEL control	Full clockwise rotation

NOTE: Unless otherwise indicated, voltages are positive. Readings were taken with a high input impedance voltmeter, from the point indicated to chassis ground.

Voltage Chart

SOCKET AND TUBE	LUG 1	LUG 2	LUG 3	LUG 4	LUG 5	LUG 6	LUG 7
V1/1U4	0	50 to 55	45 to 50	NC	0	–.35	1.4
V2/1L4	1.4	105	110	NC	1.4	.48	2.5
V3/1L4	1.4	100	110	NC	1.4	–24	2.5
V4/1U4	0	45	36	NC	0	–.5	1.4

SPECIFICATIONS

Circuit	4-arm bridge for measuring all types of impedance. Also includes a 1 kHz generator circuit and a detector circuit.
Detector	Vacuum tube type with meter rectifier. Binding posts provided for connection of external detector.
Generator	Vacuum tube type operating at 1 kHz. Binding posts provided for connection of external generator for measurements at other frequencies.
Measurements	
Resistance	0.1 Ω to 1 MΩ.
Inductance	0.1 mH to 100 H.
Capacitance	100 pF to 100 μF.
Dissipation Factor (D)	0.002 to 1.0.
Storage Factor (Q)	0.1 to 1000.
Accuracy of Bridge Circuit Components	1/2 of 1%.
Accuracy of Measurements	Limited only by interpretation of scales and quality of workmanship during assembly.
Resistance	±3%.
Inductance	±10%.
Capacitance	±3%.
Dissipation Factor (D = WCR)	±20%.
Storage Factor (Q = WL/R)	±20%.
	(Accuracy will fall off at extreme outer limits.)

Meter	Zero center, 100-0-100 μA.
Rectifier	1N191 germanium diode.
Tube Complement	
Internal Generator	1U4 (V1) and 1L4 (V2).
Internal Detector	1L4 (V3) and 1U4 (V4).
Power Supply	Power transformer.
	Half-wave, silicon diode.
	Four 1N4002 silicon diodes arranged in a full-wave, bridge-rectifier circuit.
Power Requirements	105-125 VAC or 210-250 VAC, 50/60 Hz, 10-watts. Fused with 1/8-A, slow-blow, 3AG type fuse.
Overall Dimensions	9" high x 16-1/2" wide x 6-1/2" deep.
Net Weight	11 lbs.

The Heath Company reserves the right to discontinue instruments and to change specifications at any time without incurring any obligation to incorporate new features in instruments previously sold.

BRIDGE THEORY OF OPERATION

A bridge is an arrangement of impedances used to measure various electrical properties. When used for direct current measurement of resistance, the bridge generally takes the form of the Wheatstone bridge with four resistance arms, which is the standard method for accurate measurement of resistance.

For measurement of circuit constants at audio frequencies, the alternating-current bridge is the most widely used device. Inductance and capacitance measurements are made conveniently and accurately by this method. The type of alternating current bridge circuit is determined by the measurement to be made. The circuits are all adaptations of the basic Wheatstone bridge circuit.

An important characteristic of a coil or capacitor which can be conveniently measured in an AC bridge is the ratio of resistance to reactance. This ratio is defined as the dissipation factor D. Its reciprocal is defined as the storage factor Q. The defining equations are as follows:

$$D = \frac{1}{Q} = \frac{R}{X} \qquad Q = \frac{1}{D} = \frac{X}{R}$$

where R is the series resistance and X is the reactance of the inductance or capacitance being measured.

The dissipation factor D is directly proportional to the energy dissipated per hertz, while the storage factor Q is directly proportional to the energy stored per hertz. Dissipation factor is most commonly used for capacitors because it varies directly with the loss. Storage factor Q is commonly used for inductors because it is a measurement of the voltage step-up in a tuned circuit.

In its basic form, the bridge consists of four impedance arms; A, B, C, and D; as shown in Figure 4. The ratio of A and B is switch selective so that the variable arm D can serve as a standard for measuring many values of the unknown C. The four impedances are connected in series-parallel to a source of potential, E, applied between the junctions of A/C and B/D. When the voltage drop across arm A is equal to the voltage drop across arm C, no current will flow through the detector and the bridge is in balance. This balance condition may be indicated by the formula:

$$\frac{A}{C} = \frac{B}{D}$$

Two conditions are necessary for balance. Both the magnitudes of the impedances and the phase angles must be equal.

By the proper use of resistances, capacitors, inductors, or resistor-capacitor combinations in series or parallel, the bridge may be used for measuring resistance (R), capacity (C), inductance (L), dissipation factor (D), and storage factor (Q).

Various bridge combinations are selected by setting the Function switch to the appropriate position. The ratio arms (A and B) of the bridge are selected by the Range switch. Balance is obtained by adjusting the D-Q and C-R-L dials.

RESISTANCE MEASUREMENTS

The Wheatstone bridge is still considered to be the fundamental circuit for accurate measurement of DC resistance. A 4-arm bridge, the fourth arm being the unknown as shown in Figure 5, is used for resistance measurements. The basic equation of balance for the Wheatstone bridge is:

$$R_X = \frac{R_D R_A}{R_B}$$

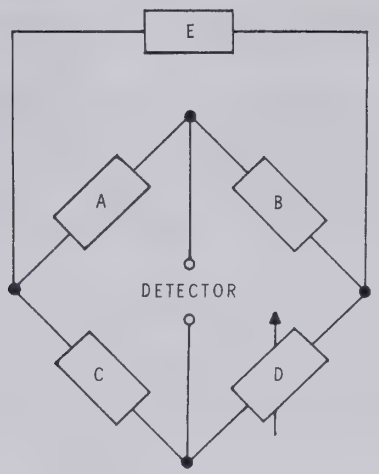
with R_X being the value of the unknown resistance. R_D is indicated by the readings of the C-R-L control dials and the ratio R_A/R_B is indicated by the dial reading of the Range switch. The value of the unknown resistance is the product of the readings of the Range switch and the C-R-L dials when the bridge is balanced.

CAPACITY MEASUREMENTS

A Capacitance-Comparison bridge is used to measure capacity. This bridge circuit uses a precision capacitor (a standard) in series with a variable resistance as shown in Figure 6. Dissipation factor is also measured using this circuit.

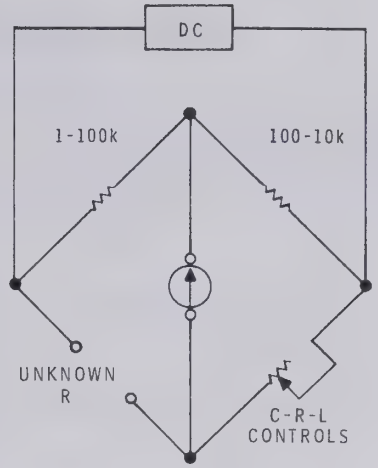
INDUCTANCE MEASUREMENTS

The Maxwell bridge circuit (Figure 7) is used to measure inductance when the storage factor (Q) of the unknown inductance is less than 10. In this bridge circuit, the inductance is measured in terms of capacitance.



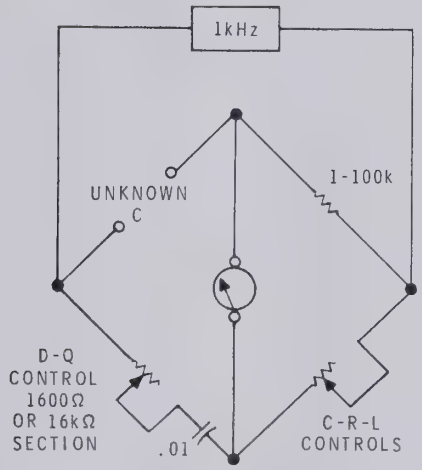
BASIC BRIDGE

Figure 4



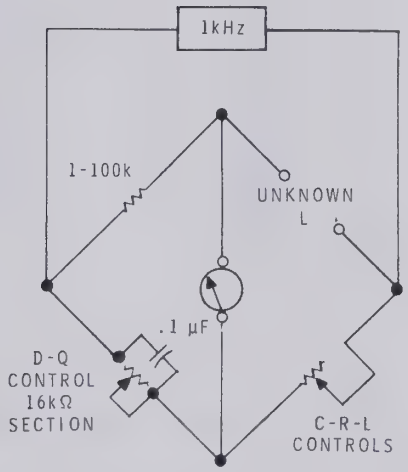
WHEATSTONE BRIDGE
(RESISTANCE)

Figure 5



COMPARISON BRIDGE
(CAPACITANCE)

Figure 6

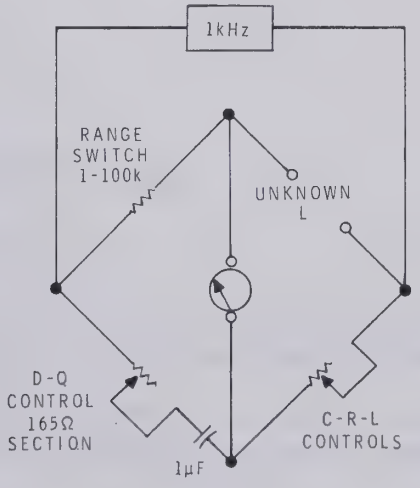


MAXWELL INDUCTANCE BRIDGE
(Q OF 0-10)

Figure 7

A capacitor has some advantages as a "standard" since practically no external field is produced and the capacitor is quite compact. In this circuit the "standard" capacitor is in parallel with the D-Q control.

The Hay bridge circuit (Figure 8) is used to measure inductances when the storage factor (Q) of the unknown inductance is between 10 and 1000. In this circuit, which is a modification of the Maxwell bridge, the "standard" capacitor is in series with the D-Q control.



HAY INDUCTANCE BRIDGE
(Q OF 10-1000)

Figure 8

D-Q CONTROL DESIGN DATA

The theoretical relationship between specific "D" or "Q" readings, as indicated by the setting of the D-Q dial and the corresponding value of resistance at that control setting, is shown in the following table. The dial's intermediate calibration marks are based on the theoretically linear characteristics of the rear and center sections (B and C) of the D-Q control and the tapered characteristic (two linear elements) in the front section (A) of the control. The overall resistance of each section of the control is held to within 5% of its specified value.

DIAL READING	SECTION A OHMS	DIAL READING	SECTION B OHMS	SECTION C OHMS
Stop	0	Stop	1600	16000
1000	1.7	10	1600	16000
500	3.27	9.0	1440	14400
400	4.1	8.0	1280	12800
300	5.95	7.0	1120	11200
200	8.1	6	960	9600
150	10.8	5	800	8000
100	16.1	4	640	6400
90	17.7	3	480	4800
80	20.1	2	320	3200
70	23.0	1	160	1600
60	26.8	0.8	128	1280
50	32.0	0.6	96	960
45	35.6	0.4	64	640
40	40.3	0.2	32	320
35	46.6	0.1	16	160
30	54.3	0	0	0
25	66.3	Stop	0	0
20	83.0			
18	92.5			
16	103.0			
14	113.0			
12	138.0			
10	165.0			
Stop	165.0			

CIRCUIT DESCRIPTION

Except for the Generator Level and the Set AC Zero controls, the front panel controls and switches function as the arms of the bridge circuitry. The remaining circuits, which are on the chassis assembly, are divided into three sections consisting of a 2-tube signal generator circuit; a 2-tube detector circuit; and associated power supply circuits. Each section will be described in the following paragraphs.

GENERATOR

NOTE: Except for resistance measurements, all bridge measurement functions require the use of a signal generator.

Tubes V1, V2, and their associated circuit components comprise a phase-shift generator having a frequency range of

approximately 800 to 1200 Hz. Trimmer capacitor C2 provides a means for setting the frequency to exactly 1 kHz. A portion of the output is coupled back through C2 to maintain the circuit in an oscillating condition. A highly accurate signal source should be used to calibrate the generator.

The 1 kHz output signal is coupled through R7 and C5 to the high side of Generator Level control R8. The 1 kHz signal at lug 2 of R8 is applied to the control grid of V2. The amount of signal applied is determined by the setting of R8. The amplified 1 kHz signal appears at the plate (pin 2) of V2. When the Generator switch is in the AC INT position, this internally generated 1 kHz signal is used for all capacitance and inductance measurements. Inductance and capacitance measurements may be made at a frequency other than 1 kHz by connecting an external generator to the External Generator binding posts and turning the Generator switch to the AC EXT position.

DETECTOR

NOTE: Except for resistance measurements, all bridge measurement functions require the use of a detector.

The detector consists of tubes V3, V4, and their associated circuit components. When the detector switch is in the AC INT position, the built-in detector circuit is used with the panel meter and becomes the null indicator. When the detector switch is in the AC EXT position, an external detector must be connected to the EXT DET binding posts. The null indicator will then be the indicator normally associated with the external detecting device. Note that a detector is used only when a measurement function requires the use of an AC signal, such as for inductance or capacitance measurements.

Set AC ZERO control R18 in series with R19 forms a divider circuit across the 135V DC source of the power supply. Adjustment of R18 will set the meter reading to the desired reference point, normally the 100 μA mark at the left end of the meter scale. Resistor R113 acts as a shunt across the meter.

Tubes V4 and V3 provide a 2-stage amplifier. Until final balance of the bridge, an AC signal will be coupled through C13 to the grid (pin 6) of V4. This signal will be amplified by V4 and V3 and appear at the plate (pin 2) of V3. This amplified signal is coupled through C9 and then rectified by meter rectifier D6 to produce a DC voltage. This DC voltage will now appear at the junction of R17 and R16 where it also is applied to the meter. This voltage is opposite in polarity to the voltage already applied to the meter. The voltage actually applied to the meter will be reduced by an amount equal to the value of the rectified signal voltage, with a resulting decrease in current flow through the meter. This "bucking" voltage will cause the meter pointer to move away from the previously set reference point. Note that the rectified signal voltage will decrease as bridge balance is approached. Therefore, when the bridge is balanced, no "bucking" voltage will be produced and the meter pointer will again read at the 100 μA reference point.

POWER SUPPLY

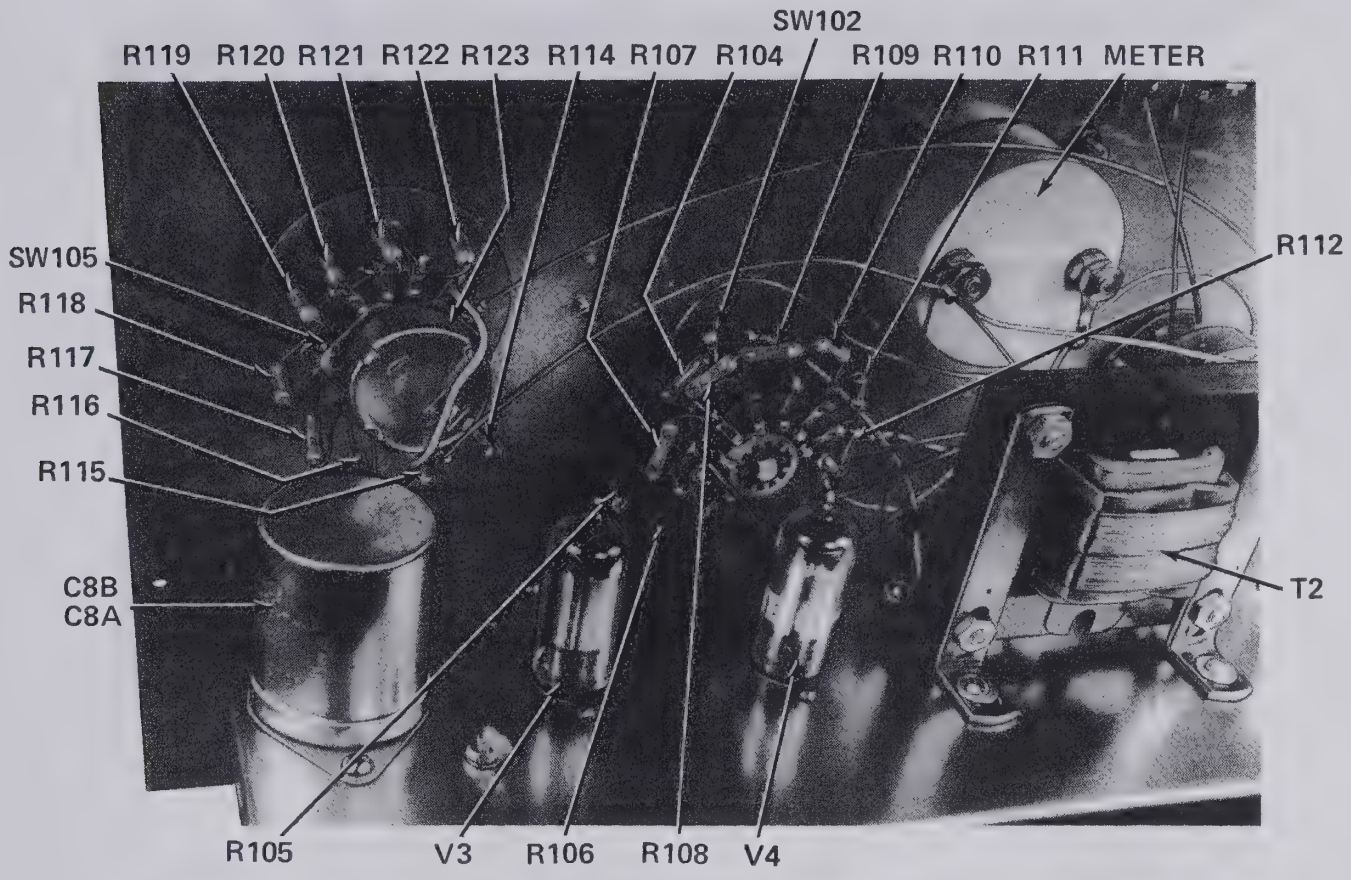
Power transformer T1 has two primary windings that can be connected for operation from a 120 volt or 240 volt 50/60 Hz power source. For 120 volt operation the primary windings are connected in parallel and for 240 volt operation they are connected in series. The primary leads must be connected as shown in the Schematic so proper phase is maintained.

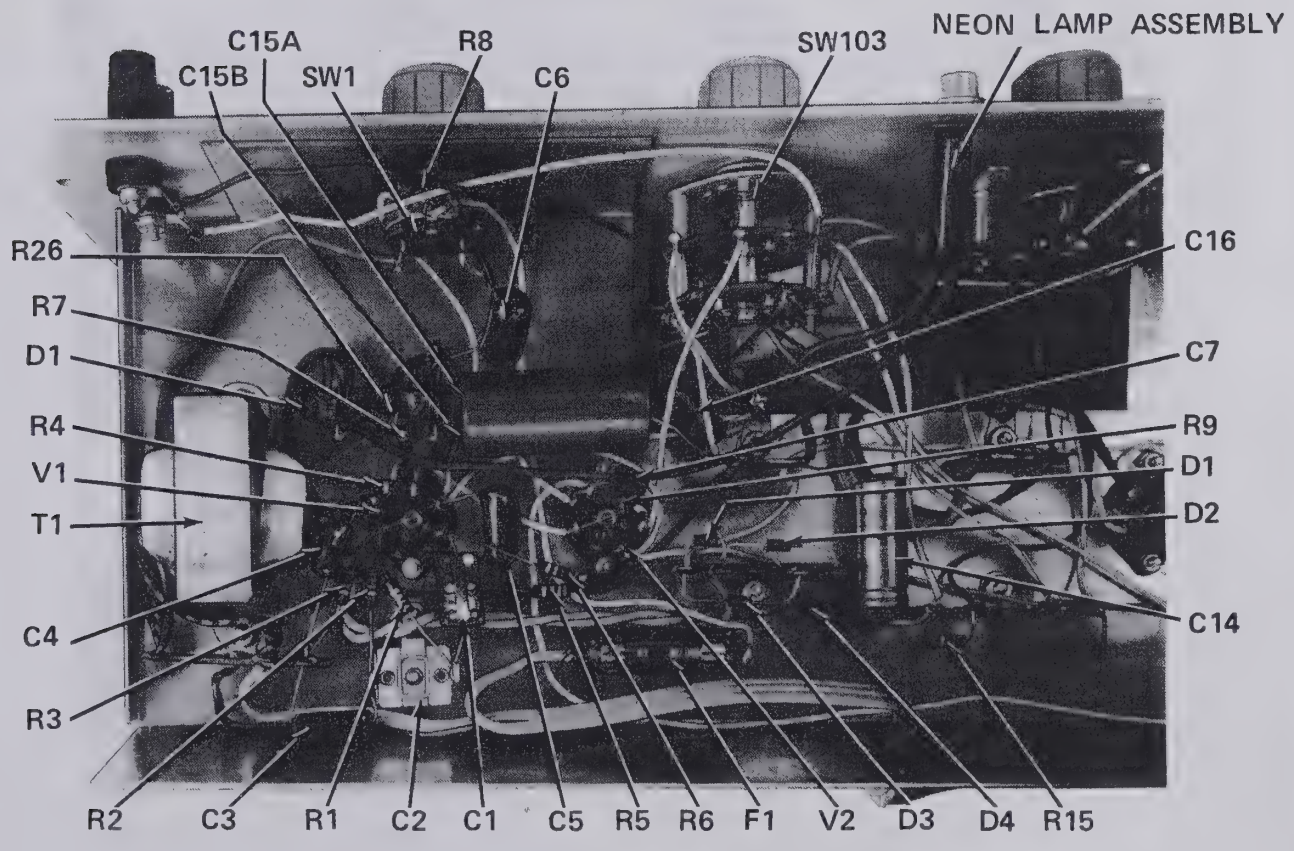
The power transformer has two secondary windings, one for the low voltage supply and one for the high voltage supply.

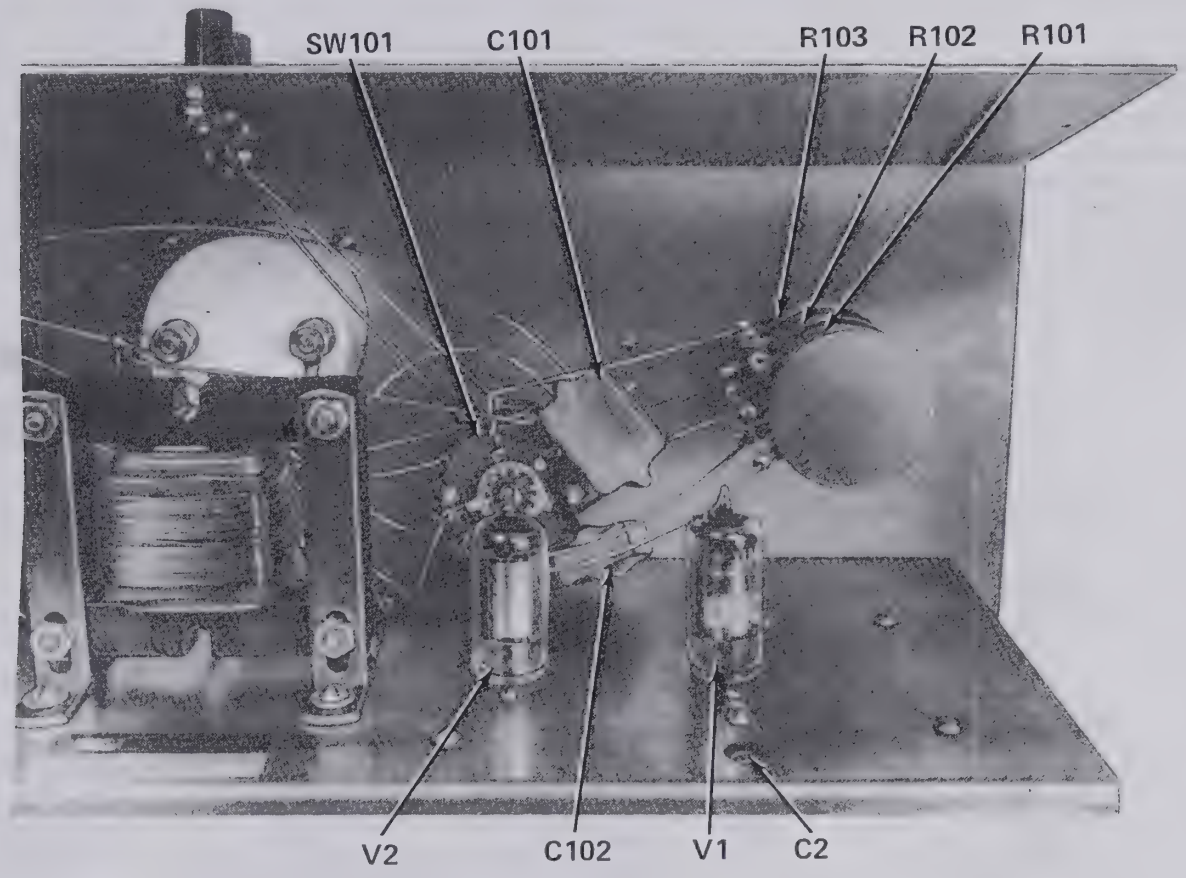
The low voltage supply uses diodes D1, D2, D3, and D4 in a full-wave, bridge-rectifier circuit; and filter capacitor C14 to provide a source of low DC voltage to light the filaments of tubes V1 through V4. With the Generator switch in the AC INT or EXT position, the output of the low voltage supply is applied through lugs 6 and 7 on wafer 1 of the Generator switch to a voltage divider/filter capacitor network consisting of resistors R10, R11, R12, R13, and capacitors C8A and C8B. The 2.5 volts DC at the junuction of R10 and R11 is applied as filament voltage between pin 7 of V2 and chassis ground. Since the filament of V1 is in series with the filament of V2, approximately 1.4 volts DC will appear between pins 1 and 7 of tubes V1 and V2. In a like manner the 2.5 volts DC at the junction of R12 and R13 is the filament voltage source for tubes V3 and V4.

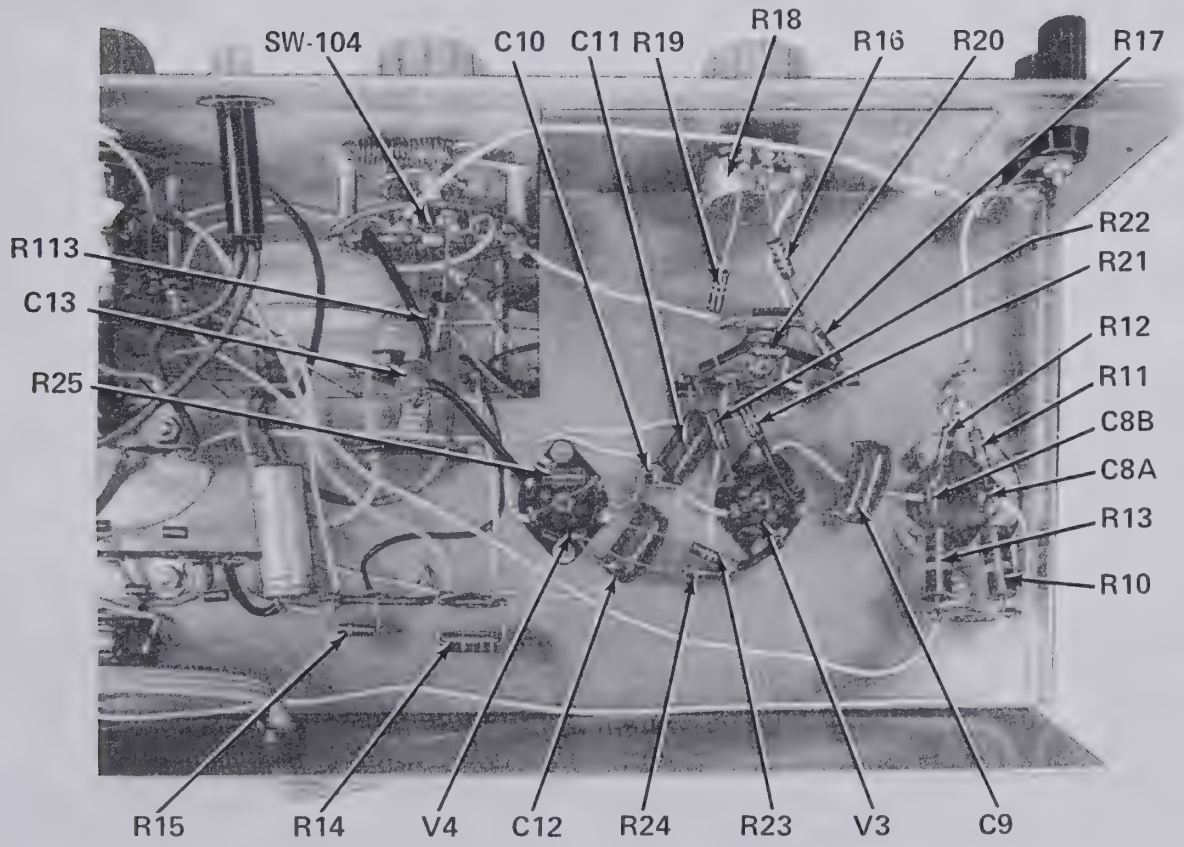
The high voltage supply uses silicon diode D5, capacitor C15A, resistor R26, and capacitor C15B in a half-wave rectifier circuit to provide a source of high voltage of approximately 135 volts DC. With the exception of the tube filament voltages, this supply provides plate, screen, and all other voltages necessary for operation of the Impedance Bridge.

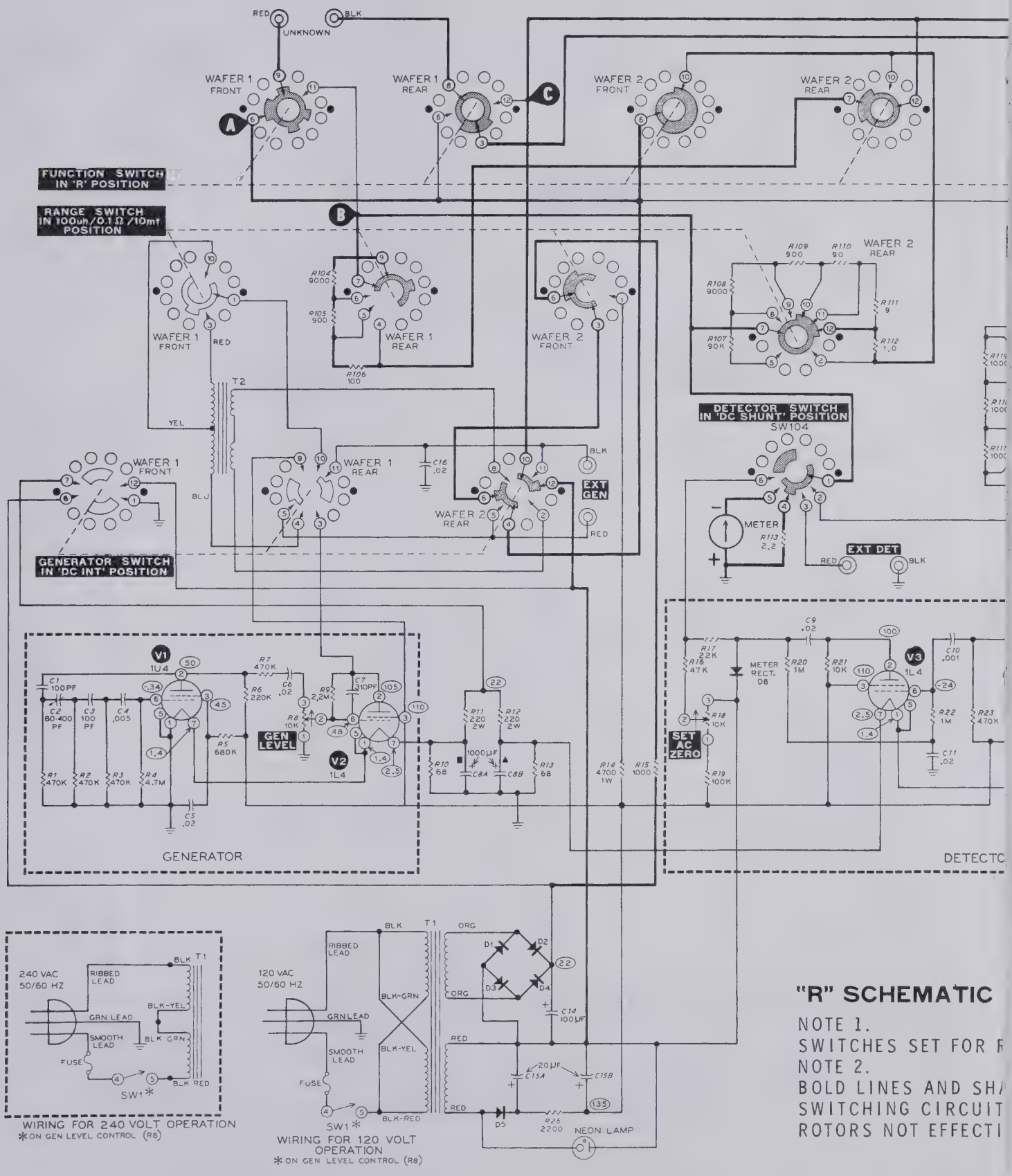
IDENTIFICATION PHOTOGRAPHS





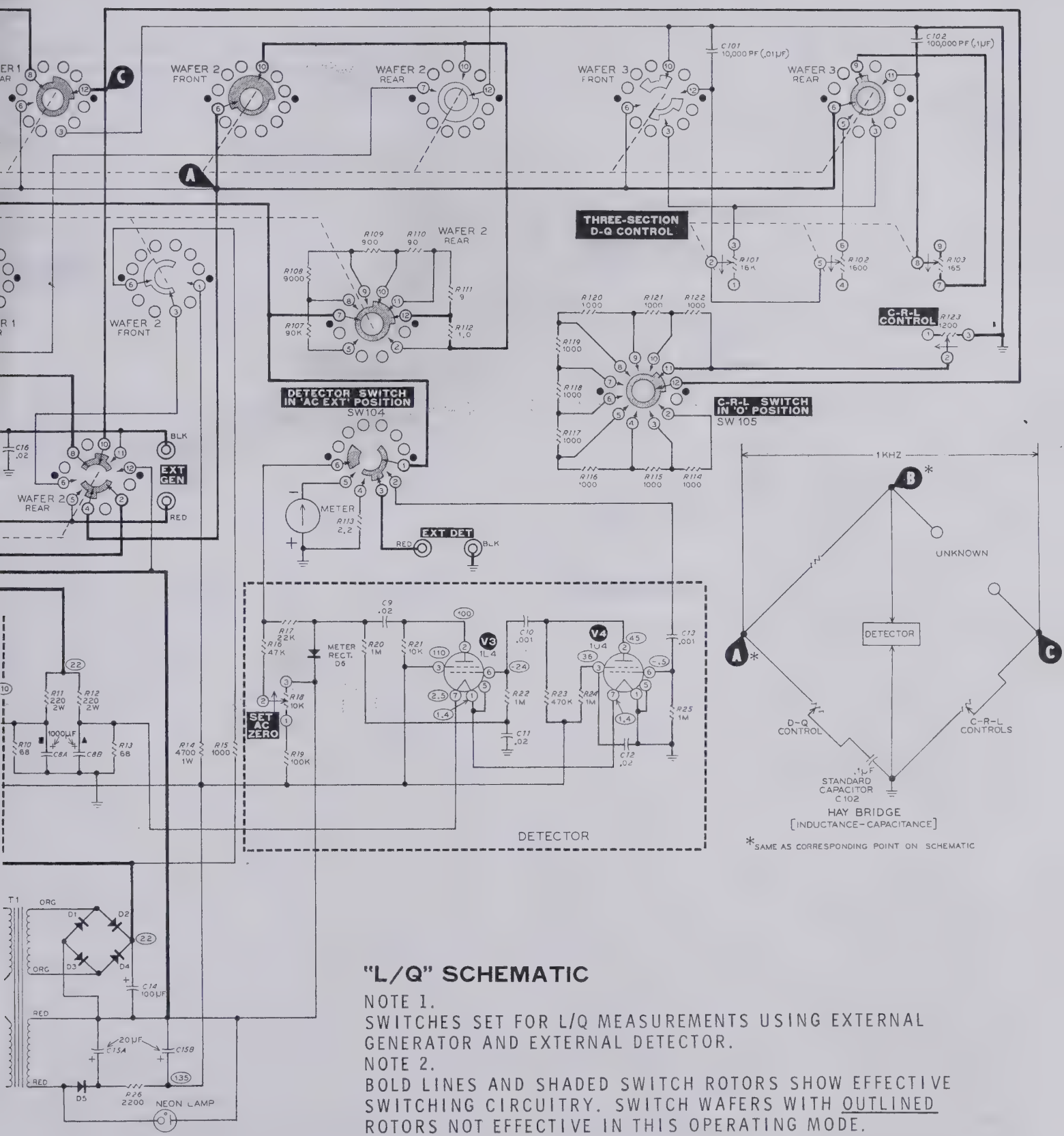

SW101
C101
R103
R102
R101
V2
C102
V1
C2


SW-104
C10
C11
R19
R18
R16
R20
R17
R113
C13
R25
R22
R21
R12
R11
C8B
C8A
R13
R10
R15
R14
V4
C12
R24
R23
V3
C9



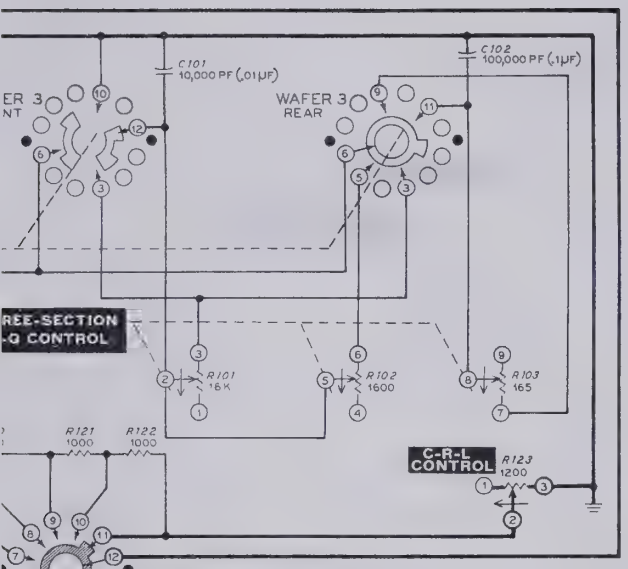
"R" SCHEMATIC

NOTE 1.
SWITCHES SET FOR R
NOTE 2.
BOLD LINES AND SHA
SWITCHING CIRCUIT
ROTORS NOT EFFECTI

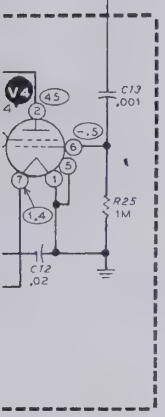


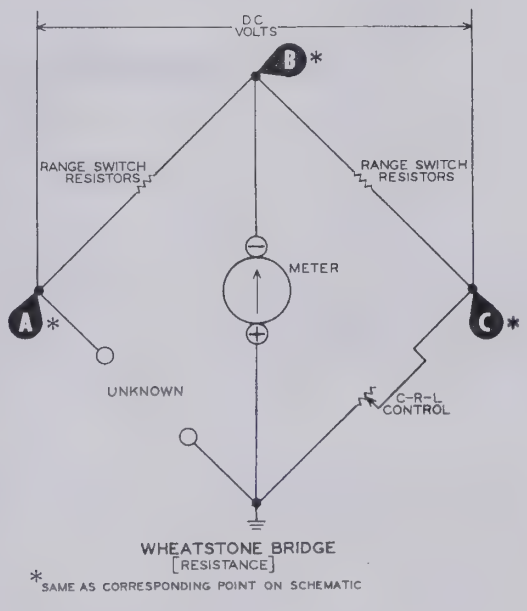
"L/Q" SCHEMATIC

NOTE 1.
SWITCHES SET FOR L/Q MEASUREMENTS USING EXTERNAL GENERATOR AND EXTERNAL DETECTOR.
NOTE 2.
BOLD LINES AND SHADED SWITCH ROTORS SHOW EFFECTIVE SWITCHING CIRCUITRY. SWITCH WAFERS WITH OUTLINED ROTORS NOT EFFECTIVE IN THIS OPERATING MODE.

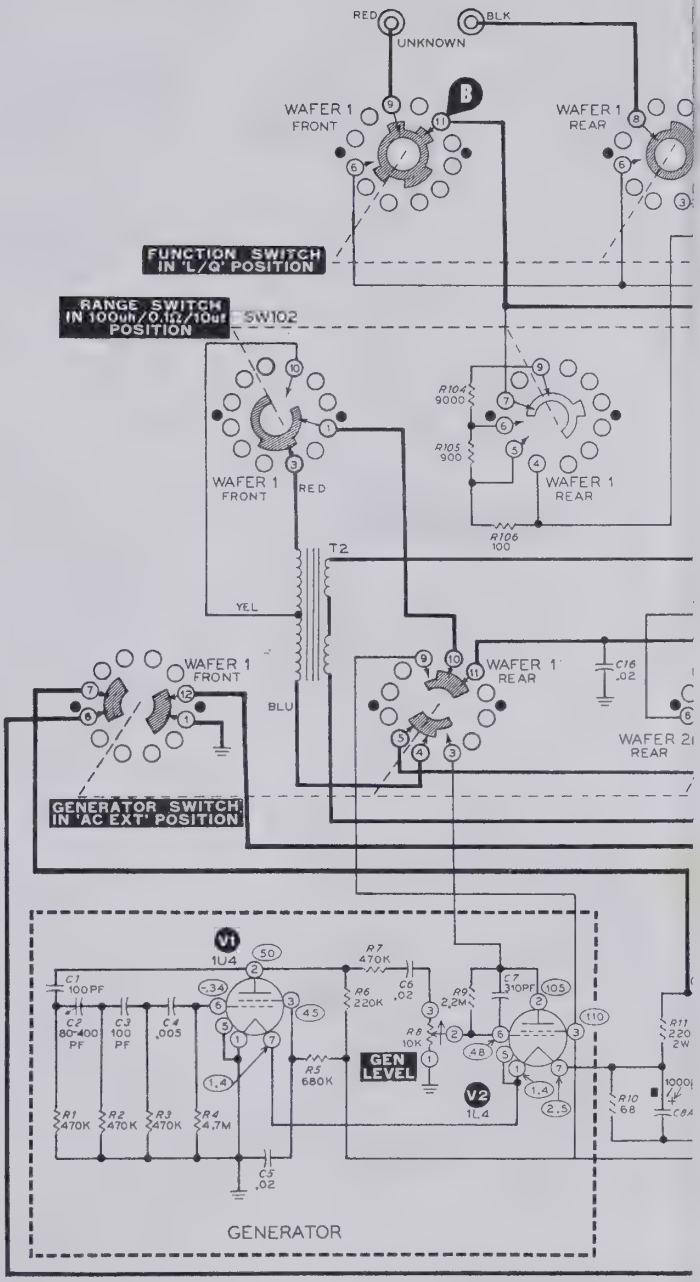


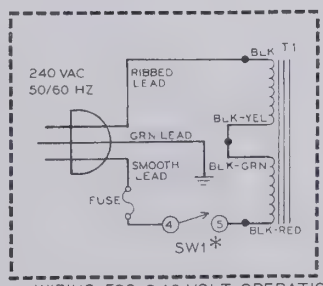
C-R-L SWITCH IN 'O' POSITION
SW 105



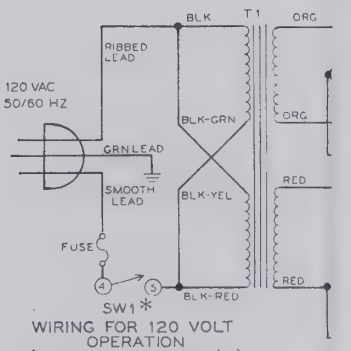


WHEATSTONE BRIDGE
[RESISTANCE]
* SAME AS CORRESPONDING POINT ON SCHEMATIC





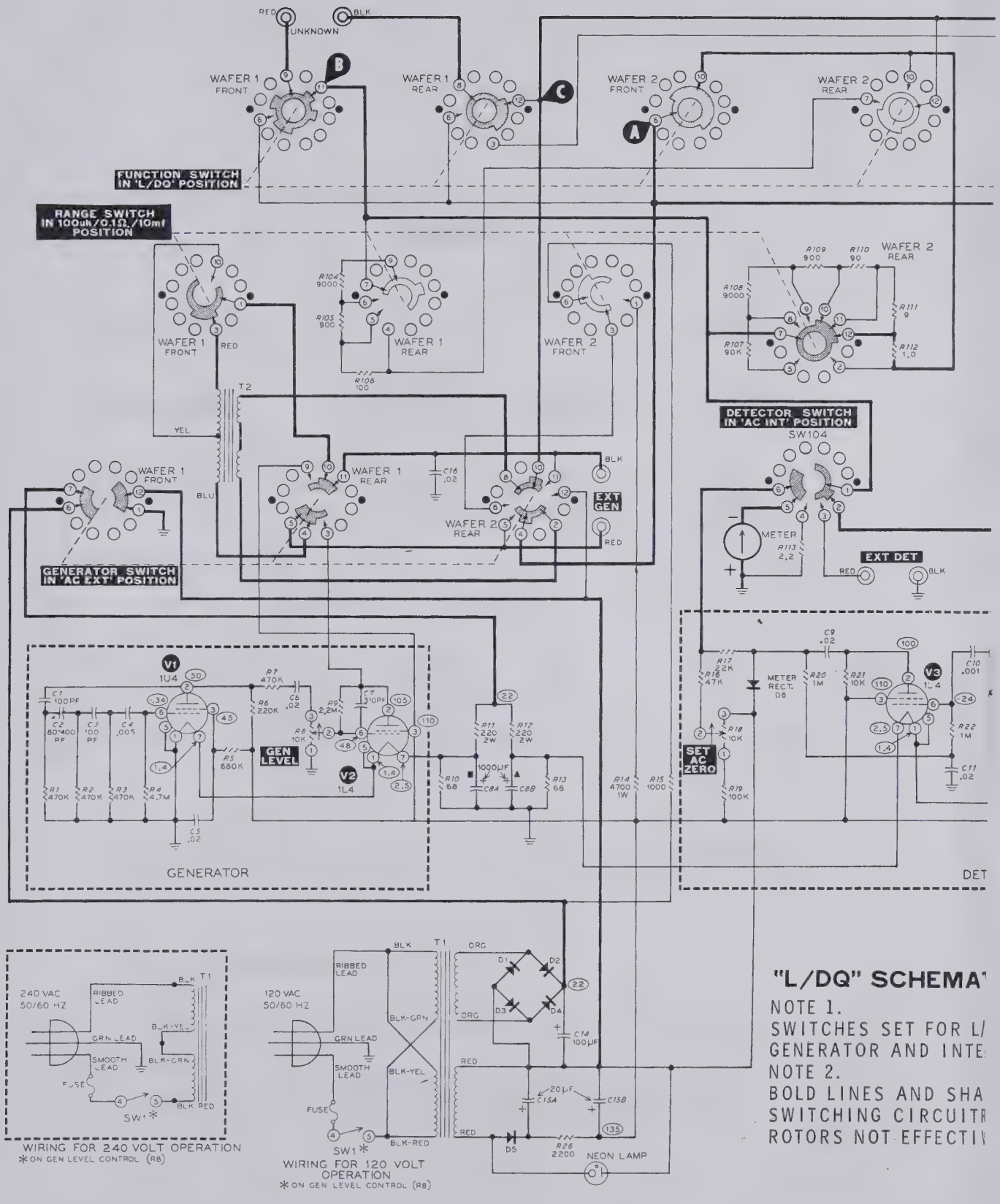
WIRING FOR 240 VOLT OPERATION
* ON GEN LEVEL CONTROL (R8)



WIRING FOR 120 VOLT OPERATION
* ON GEN LEVEL CONTROL (R8)

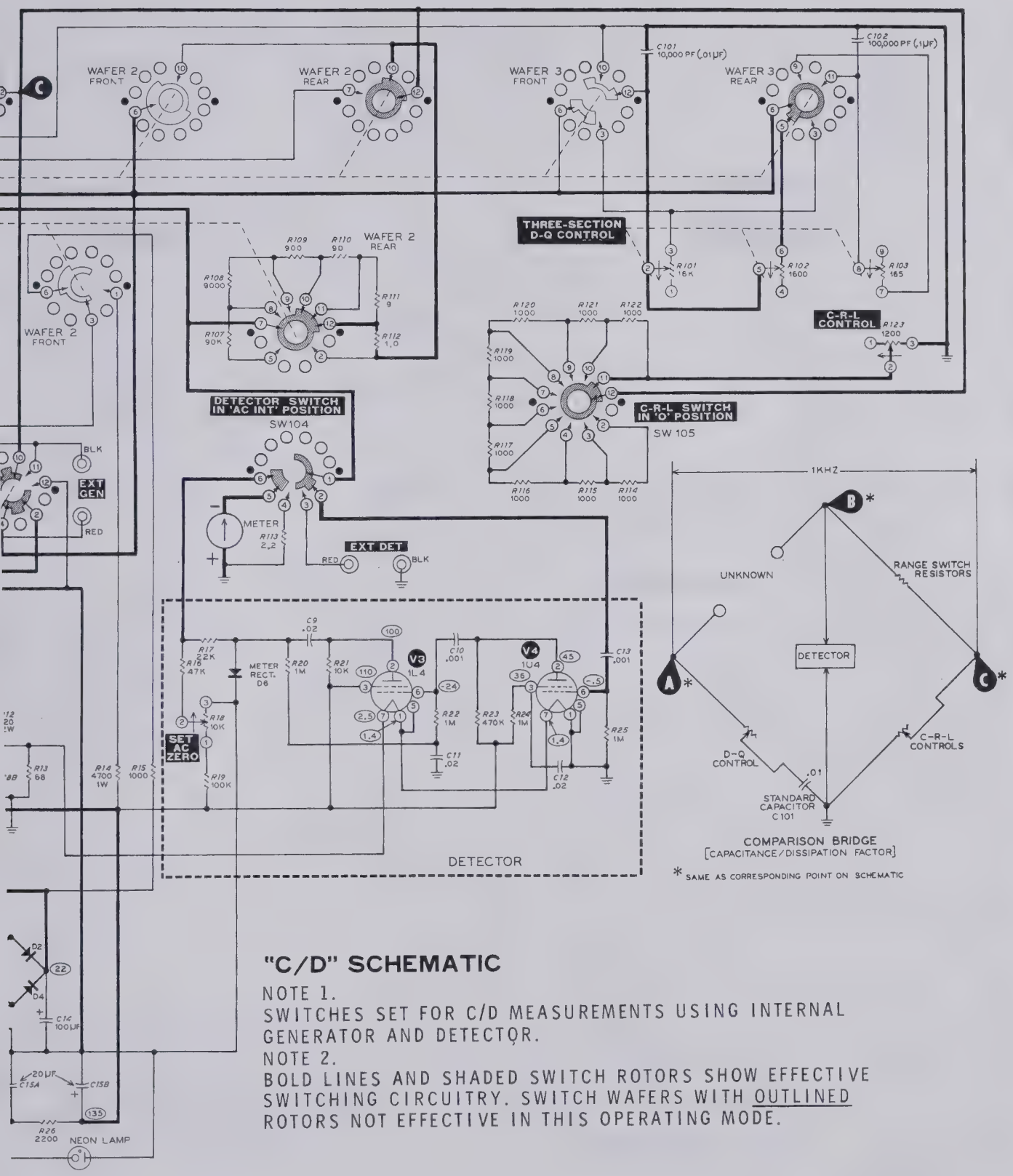
IEASUREMENTS.

ED SWITCH ROTORS SHOW EFFECTIVE
'. SWITCH WAFERS WITH OUTLINED
IN THIS OPERATING MODE.



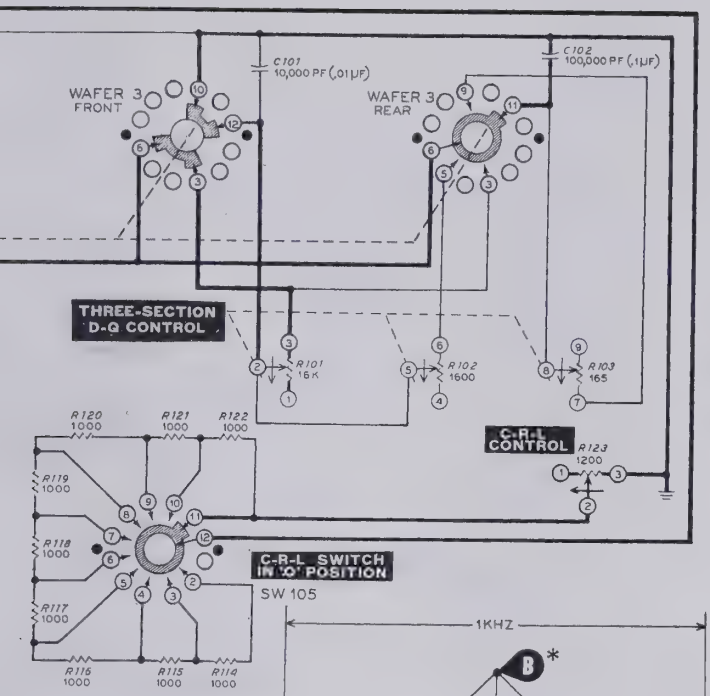
"L/DQ" SCHEMA

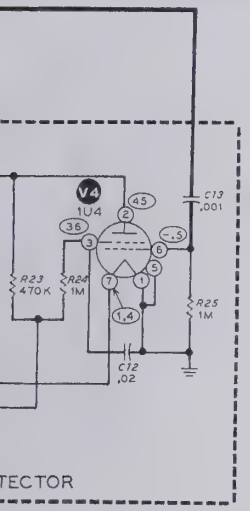
NOTE 1.
SWITCHES SET FOR L/
GENERATOR AND INTE
NOTE 2.
BOLD LINES AND SHA
SWITCHING CIRCUITR
ROTORS NOT EFFECTI

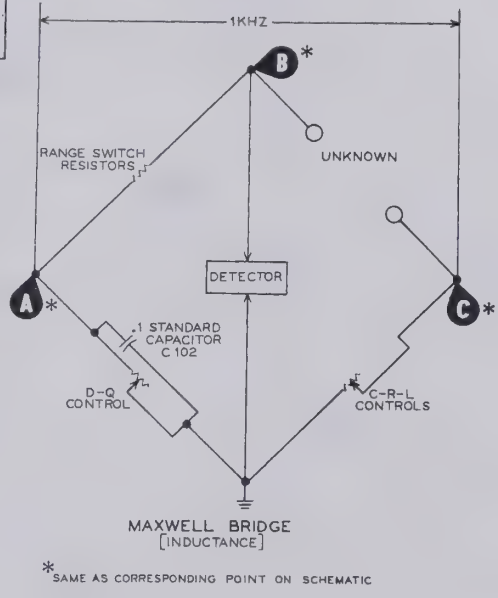


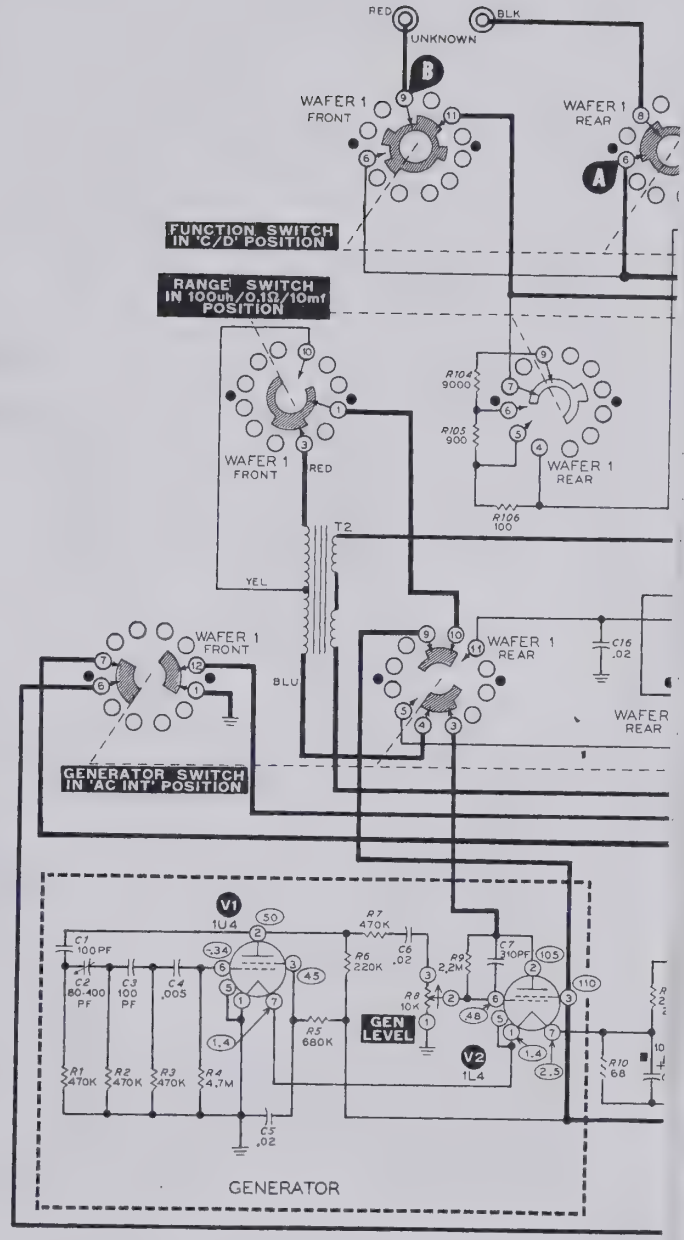
"C/D" SCHEMATIC

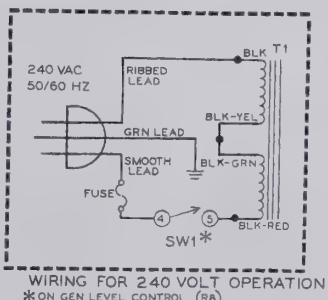
NOTE 1.
SWITCHES SET FOR C/D MEASUREMENTS USING INTERNAL GENERATOR AND DETECTOR.
NOTE 2.
BOLD LINES AND SHADED SWITCH ROTORS SHOW EFFECTIVE SWITCHING CIRCUITRY. SWITCH WAFERS WITH OUTLINED ROTORS NOT EFFECTIVE IN THIS OPERATING MODE.



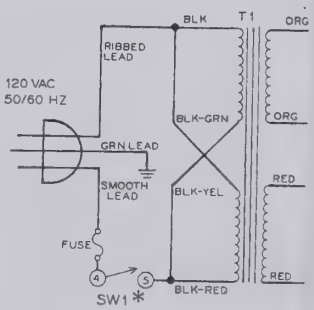








WIRING FOR 240 VOLT OPERATION
*ON GEN LEVEL CONTROL (R8)

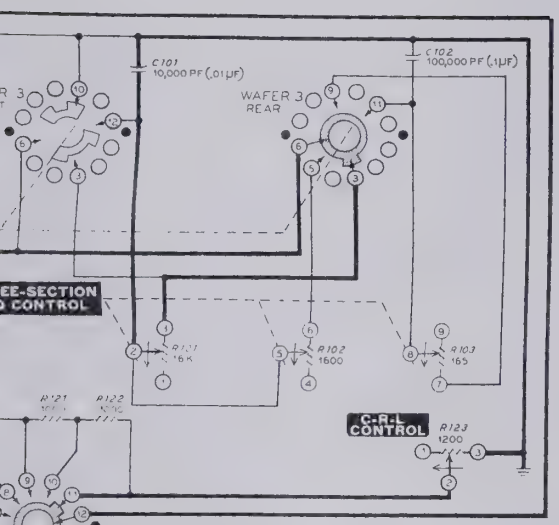


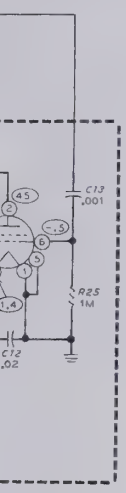
WIRING FOR 120 VOLT OPERATION
*ON GEN LEVEL CONTROL (R8)

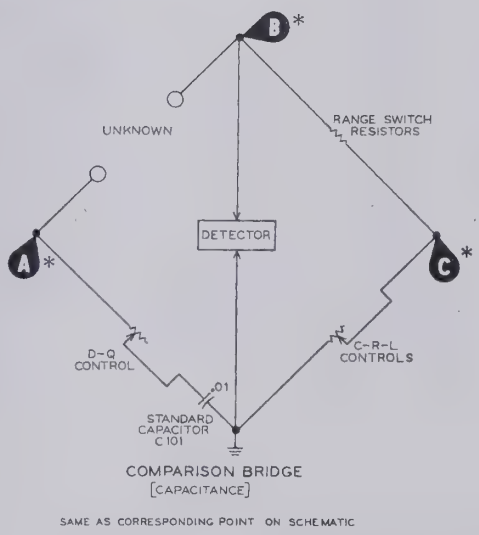
TIC

/DQ MEASUREMENTS USING EXTERNAL
RNAL DETECTOR.

DED SWITCH ROTORS SHOW EFFECTIVE
RY. SWITCH WAFERS WITH OUTLINED
VE IN THIS OPERATING MODE.

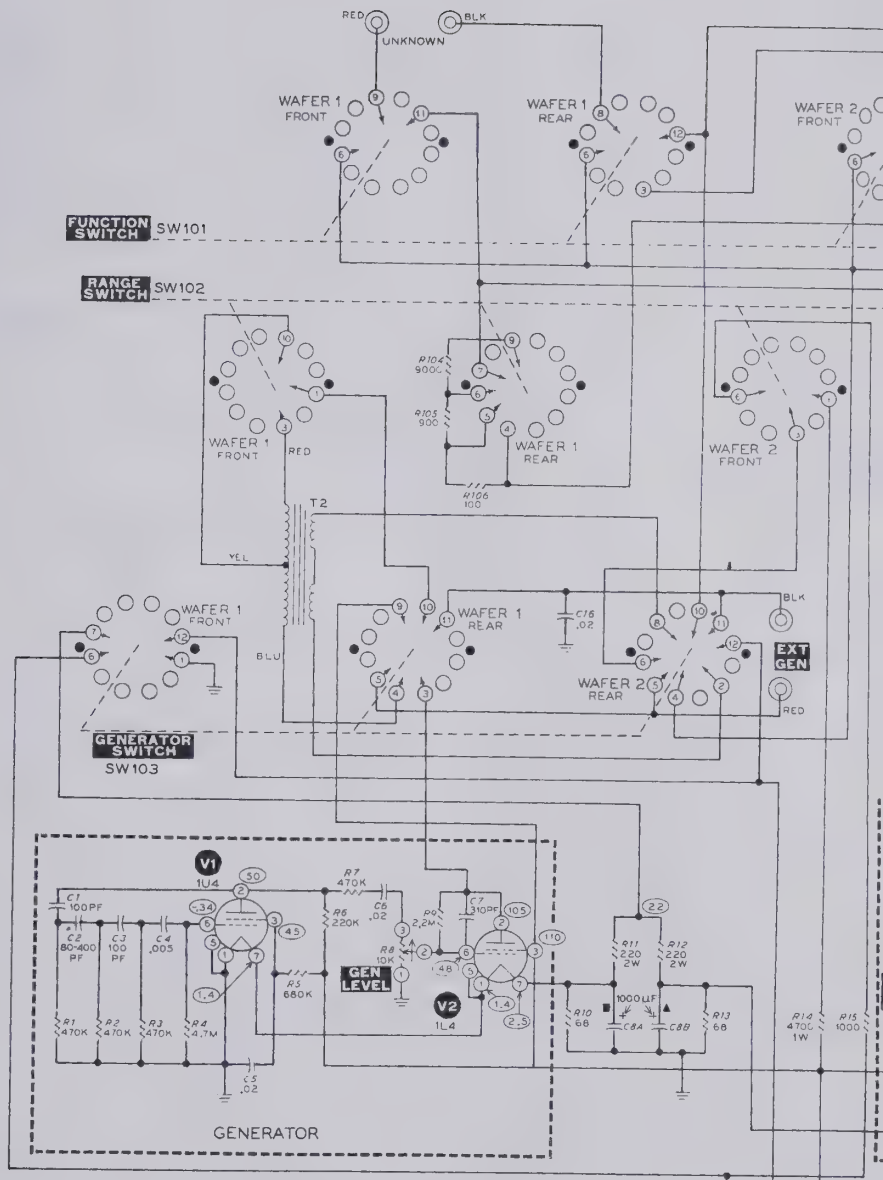




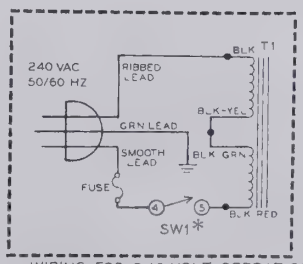


COMPARISON BRIDGE
[CAPACITANCE]

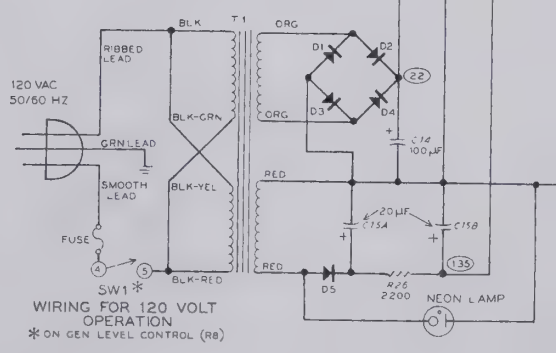
SAME AS CORRESPONDING POINT ON SCHEMATIC



GENERATOR



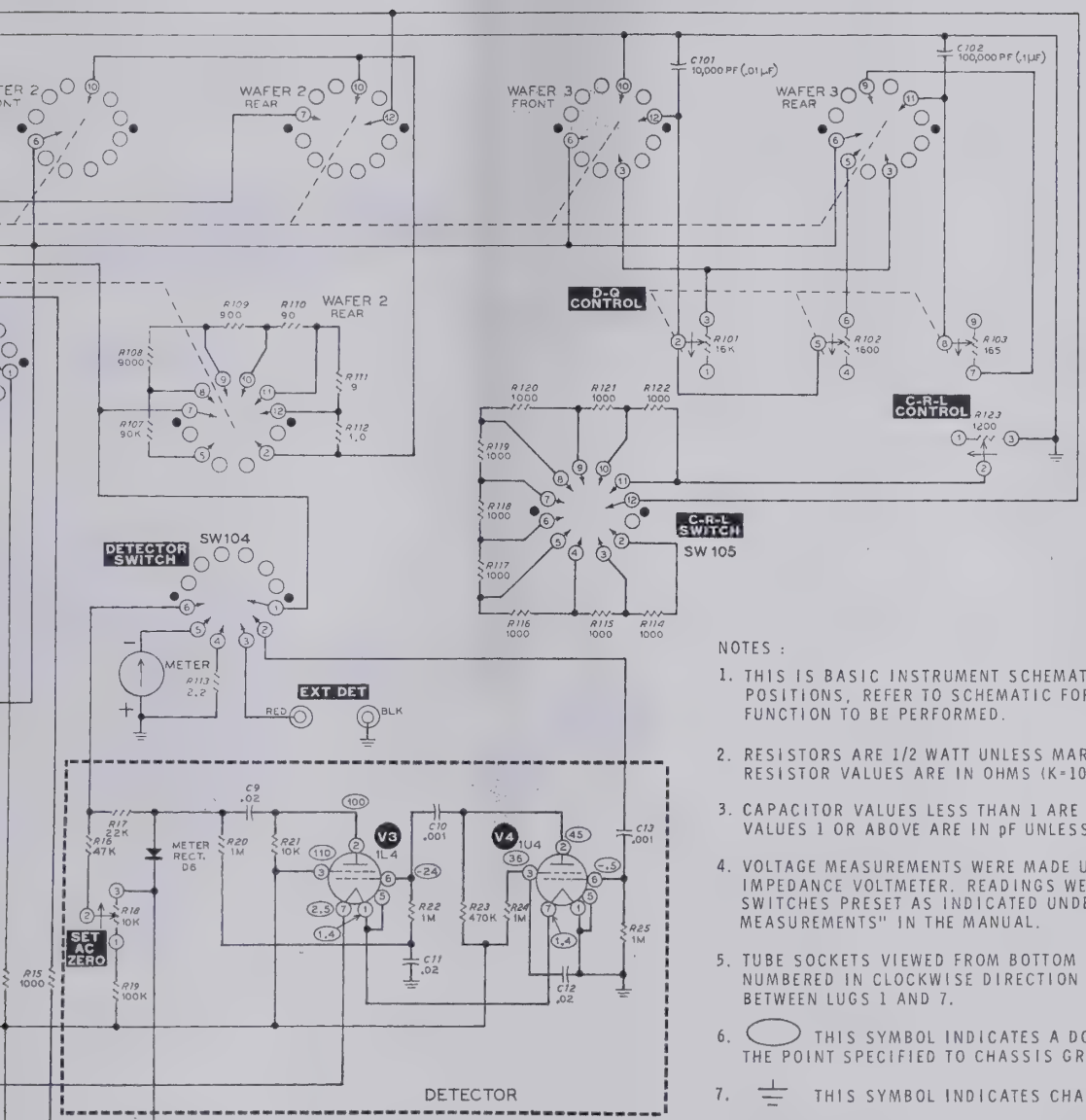
WIRING FOR 240 VOLT OPERATION
*ON GEN LEVEL CONTROL (R8)



WIRING FOR 120 VOLT
OPERATION
*ON GEN LEVEL CONTROL (R8)

ASUREMENTS USING INTERNAL
ETECTOR.

VITCH ROTORS SHOW EFFECTIVE
ITCH WAFERS WITH OUTLINED
HIS OPERATING MODE.



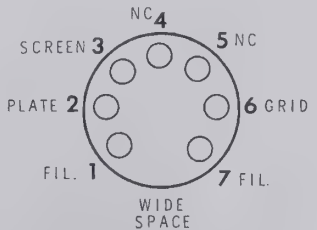
SCHEMATIC OF THE HEATHKIT® IMPEDANCE BRIDGE MODEL IB-28

NOTES :

1. THIS IS BASIC INSTRUMENT SCHEMATIC. FOR SWITCH POSITIONS, REFER TO SCHEMATIC FOR SPECIFIC MEASUREMENT FUNCTION TO BE PERFORMED.
2. RESISTORS ARE 1/2 WATT UNLESS MARKED OTHERWISE. RESISTOR VALUES ARE IN OHMS (K=1000, M=1,000,000).
3. CAPACITOR VALUES LESS THAN 1 ARE IN μF. CAPACITOR VALUES 1 OR ABOVE ARE IN pF UNLESS MARKED OTHERWISE.
4. VOLTAGE MEASUREMENTS WERE MADE USING A HIGH INPUT IMPEDANCE VOLTMETER. READINGS WERE OBTAINED WITH THE SWITCHES PRESET AS INDICATED UNDER "VOLTAGE MEASUREMENTS" IN THE MANUAL.
5. TUBE SOCKETS VIEWED FROM BOTTOM OF CHASSIS. LUGS ARE NUMBERED IN CLOCKWISE DIRECTION FROM WIDE SPACE BETWEEN LUGS 1 AND 7.
6. ⬭ THIS SYMBOL INDICATES A DC VOLTAGE MEASURED FROM THE POINT SPECIFIED TO CHASSIS GROUND.
7. ⏚ THIS SYMBOL INDICATES CHASSIS GROUND.
8. COMPONENTS WITHIN DASHED LINES COMPRISE BUILT-IN GENERATOR AND DETECTOR CIRCUITS.
9. COMPONENTS ARE NUMBERED AS FOLLOWS:

1 - 50	CHASSIS MOUNTED PARTS
101 - 125	PANEL MOUNTED PARTS

10. ARROWS ON CONTROLS INDICATE CLOCKWISE ROTATION AS VIEWED FROM SHAFT END OF CONTROL.



TUBE BASING DIAGRAM
(BOTTOM VIEW)

Assembly and Operation of the

HEATHKIT

IMPEDANCE BRIDGE

MODEL IB-28

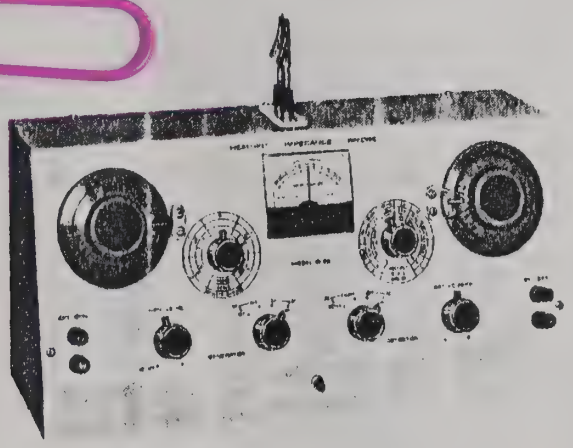


Table of Contents

HEATH COMPANY
BENTON HARBOR, MICHIGAN 49022

INTRODUCTION

The Heathkit Model IB-28 Impedance Bridge is a self-contained, direct-reading precision instrument for accurate and rapid measurement of resistance, capacitance, inductance, dissipation factor of capacitors, and storage factor of inductors. A 4-arm bridge, using precision components, is the heart of the instrument. It can be switched into a number of basic bridge circuits.

Bridge balance is indicated by a 100-0-100 microammeter. A suitable shunt protects the meter against accidental overload and may be switched out of the meter circuit during final balance to provide maximum null sensitivity.

A built-in, vacuum tube, phase-shift generator with a frequency range of approximately 800 to 1200 Hz is provided for measurement functions that require the use of an AC signal. An adjustable trimmer capacitor is used to set the frequency of the internal generator to exactly 1000 Hz. Binding posts on the front panel allow connection of an external generator or frequency standard so measurements can be made at a frequency other than that provided by the built-in generator.

A built-in vacuum tube amplifier and detector, in conjunction with the zero center microammeter, provides a very sensitive null indicating circuit for inductance and capacitance measurements. Front panel binding posts allow an external detecting device to be used instead of the built-in null indicating circuitry. Bridge balance is then indicated by the readout device normally used with the external detector.

The external generator binding posts and the external detector binding posts can be used when the appropriate Generator and/or Detector switch is in the AC EXT position.

Refer to the "Kit Builders Guide" for complete information on unpacking, parts identification, tools, wiring, soldering, and step-by-step assembly procedures.

PARTS LIST

Check each part against the following list. The key numbers correspond to the numbers on the "Parts Pictorial" (fold-out from Page 5). Any part that is packaged in an individual envelope with a part number on it, should be placed back in its envelope after it is identified and until it is called for later.

To order a replacement part, use the Parts Order Form furnished with this kit. If a Parts Order Form is not available, refer to "Replacement Parts" inside the rear cover of the Manual.

KEY No.	PART No.	PARTS Per Kit	DESCRIPTION	PRICE Each
RESISTORS				
1/2-Watt				
A1	1-2	2	68 Ω (blue-gray-black)	
A1	1-9	1	1000 Ω (brown-black-red)	
A1	1-44	1	2200 Ω (red-red-red)	
A1	1-20	1	10 kΩ (brown-black-orange)	
A1	1-22	1	22 kΩ (red-red-orange)	
A1	1-25	1	47 kΩ (yellow-violet-orange)	
Resistors (cont'd.)				
A1	1-26	1	100 kΩ (brown-black-yellow)	
A1	1-29	1	220 kΩ (red-red-yellow)	
A1	1-33	5	470 kΩ (yellow-violet-yellow)	
A1	1-34	1	680 kΩ (blue-gray-yellow)	
A1	1-35	4	1 MΩ (brown-black-green)	
A1	1-37	1	2.2 MΩ (red-red-green)	
A1	1-71	1	4.7 MΩ (yellow-violet-green)	
Precision				
A2	2-1	1	1 Ω	
A2	2-2	1	9 Ω	
A2	2-3	1	90 Ω	
A2	2-4	1	100 Ω	
A2	2-59	1	550 Ω	
A2	2-5	2	900 Ω	
A2	2-6	9	1000 Ω (1 k)	
A2	2-7	2	9000 Ω (9 k)	
A2	2-10	1	90 kΩ	
Other Resistors				
A3	1-24-1	1	4700 Ω, 1-watt (yellow-violet-red)	
A3	3-5-2	1	2.2 Ω, 2-watt (red-red-gold)	
A4	1-13-2	2	220 Ω, 2-watt (red-red-brown)	
CAPACITORS				
B1	20-11	2	100 pF mica	
B2	20-112	1	310 pF mica	
B3	20-27	1	.01 μF (10,000 pF) mica	
B4	20-28	1	.1 μF (100,000 pF) mica	
B5	21-140	2	.001 μF disc	
B6	27-115	1	.005 μF Mylar*	
B6	27-116	6	.02 μF Mylar	
B7	25-206	1	20/20 μF electrolytic	
B8	25-28	1	100 μF electrolytic	
B9	25-26	1	1000/1000 μF electrolytic	
B10	31-9	1	80-400 pF trimmer	
CONTROLS-SWITCHES				
C1	10-262	1	10 kΩ control	
C2	13-2	1	165 Ω/1600 Ω/16 kΩ, 3-section control	
C3	19-36	1	1250 Ω control w/10-position switch	
C4	19-127	1	10 kΩ control w/switch	
C5	63-512	1	4-position spring-loaded switch	
C6	63-513	1	4-position, 2-section switch	
C7	63-514	1	8-position, 2-section switch	
C8	63-515	1	5-position, 3-section switch	

*DuPont Registered Trademark

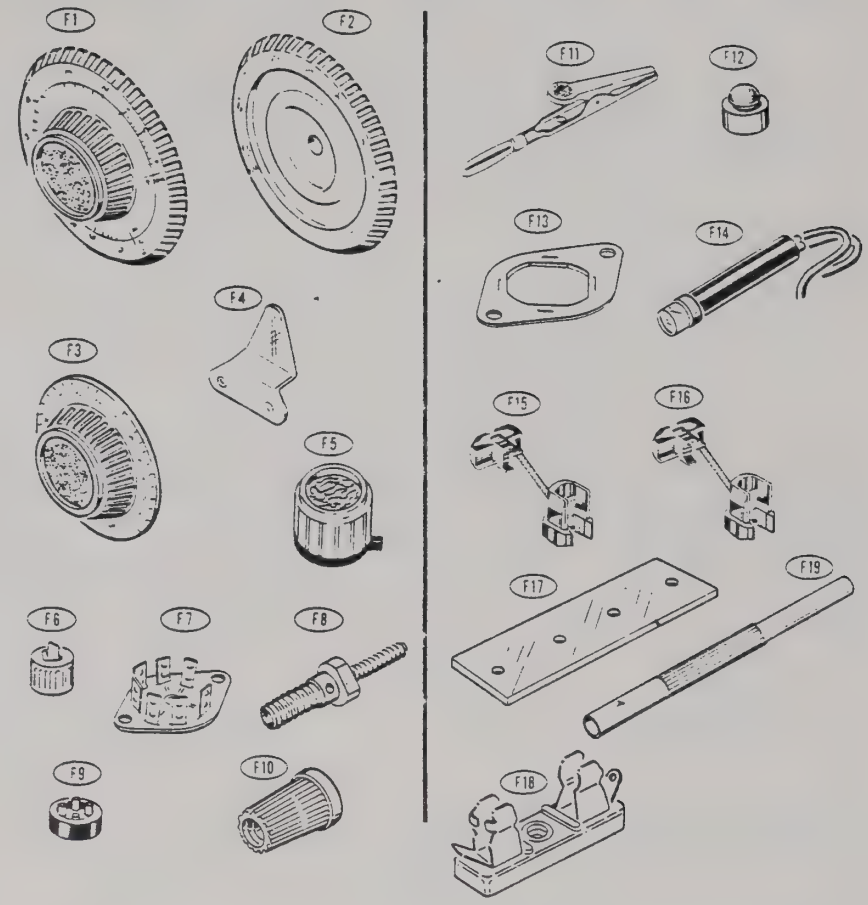
KEY No.	PART No.	PARTS Per Kit	DESCRIPTION	PRICE Each
HARDWARE				
#6 Hardware				
D1	250-9	15	6-32 x 3/8" screw	
D2	250-29	3	6-32 x 3/4" screw	
D3	250-8	13	#6 x 3/8" sheet metal screw	
D4	252-3	28	6-32 nut	
D5	254-1	26	#6 lockwasher	
D6	254-6	2	#6 external tooth lockwasher	
D7	259-1	9	#6 solder lug	
D8	255-15	3	#6 x 1/2" spacer	
Other Hardware				
D9	250-2	8	3-48 x 5/16" screw	
D10	252-1	8	3-48 nut	
D11	254-7	8	#3 lockwasher	
D12	253-9	4	#8 flat washer	
D13	252-7	8	Control nut	
D14	254-5	8	Control lockwasher	
D15	253-10	7	Control flat washer	
D16	252-73	1	Push-on nut	
METAL PARTS-WIRE-SLEEVING				
E1	200-528	1	Chassis	
E2	203-542	1	Panel	
E3	204-52	1	Mounting bracket	
	90-417	1	Cabinet	
	340-3	1	Bare solid wire	/ft
	344-50	1	Black wire	/ft
	344-59	1	White wire	/ft
	344-52	1	Red wire	/ft
	344-54	1	Yellow wire	/ft
	89-23	1	Line cord	
	346-1	1	Sleeving	/ft
TERMINAL STRIPS-RECTIFIERS-DIODES				
E4	431-1	3	1-lug terminal strip	
E5	431-2	2	2-lug terminal strip	
E6	431-51	1	2-lug vertical-mount terminal strip	
E7	431-5	4	4-lug terminal strip	
E8	56-26	1	1N191 germanium diode (brown-white-brown)	
E8	57-27	1	1N2071 silicon diode	
E8	57-65	4	1N4002 silicon diode	

KEY No.	PART No.	PARTS Per Kit	DESCRIPTION	PRICE Each
DIALS-KNOBS-INSERTS-SOCKETS				
F1	462-283	1	D-Q dial	
F2	462-284	1	C-R-L control dial	
F3	462-285	1	C-R-L switch dial	
F4	463-5	2	Dial pointer	
F5	462-245	6	Knob	
F6	455-50	6	Knob insert	
F7	434-15	4	7-pin socket	
MISCELLANEOUS				
F8	427-3	6	Binding post base	
F9	75-17	8	Binding post insulator	
F10	100-16-2	3	Black binding post cap	
F10	100-16-18	3	Red binding post cap	
F11	438-14	2	Banana plug with clip	
F12	261-1	4	Rubber foot	
F13	481-1	1	Capacitor mounting wafer	
F14	412-24	1	Neon lamp assembly	
F15	75-71	1	Strain relief (for flat cord)	
F16	75-30	1	Strain relief (for round cord)	
F17	75-6	1	Terminal board insulator	
	421-26	1	Fuse (3AG, 1/8-A, slow-blow)	
F18	422-1	1	Fuse block	
F19	490-5	1	Nut starter	

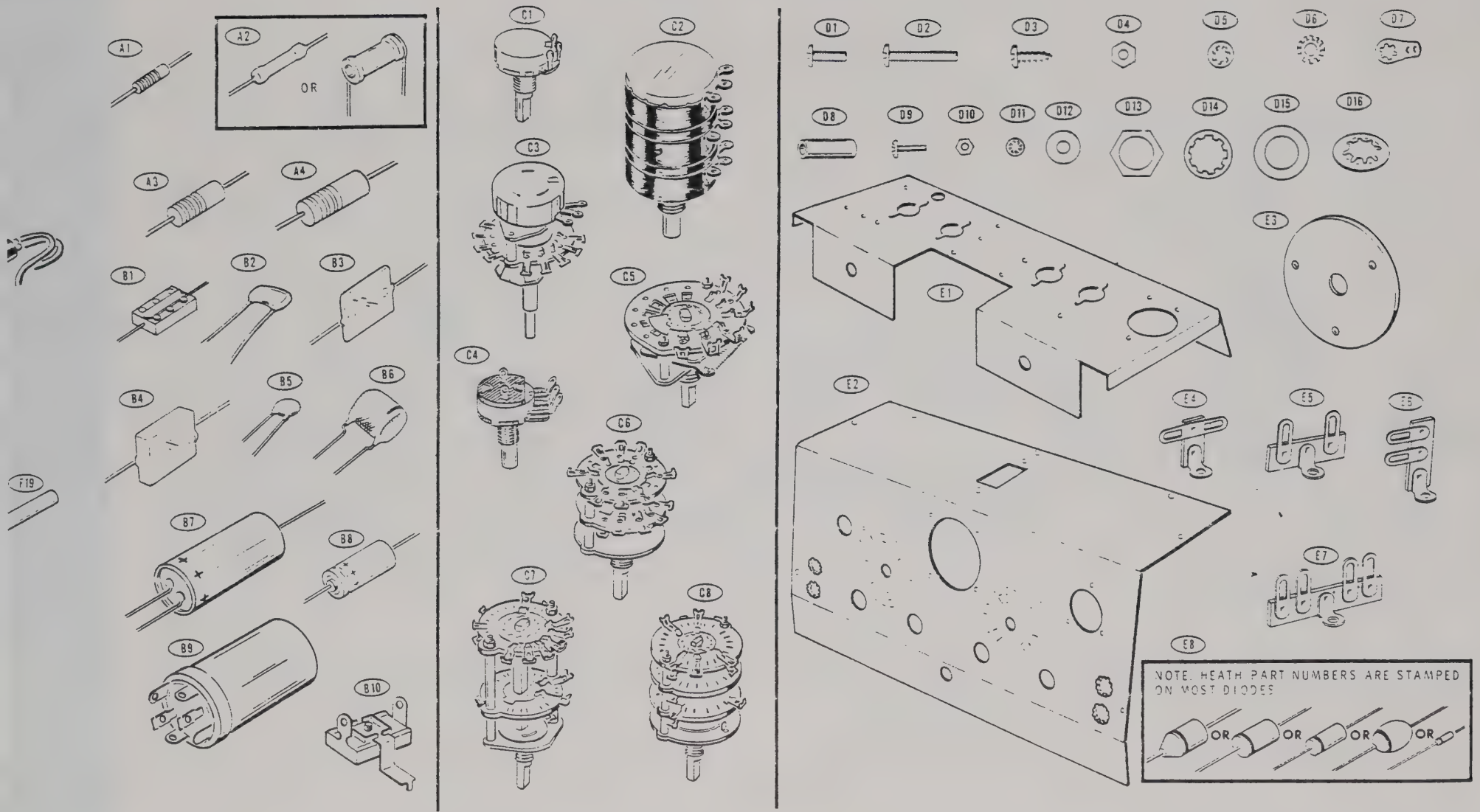
KEY No.	PART No.	PARTS Per Kit	DESCRIPTION	PRICE Each
Miscellaneous (cont'd.)				
	51-16	1	Bridge transformer	
	54-56-24	1	Power transformer	
	407-4	1	Meter	
	411-56	2	1U4 tube	
	411-57	2	1L4 tube	
	432-27	1	Line cord plug adapter	
	390-362	1	Fuse label	
	391-34	1	Blue and white identification label	
	597-308	1	Kit Builders Guide	
	597-260	1	Parts Order Form	
		1	Manual (See front cover for part number.)	
	331-8		Solder (Additional 3' rolls of solder, #331-6, can be ordered for 15 cents each.)	

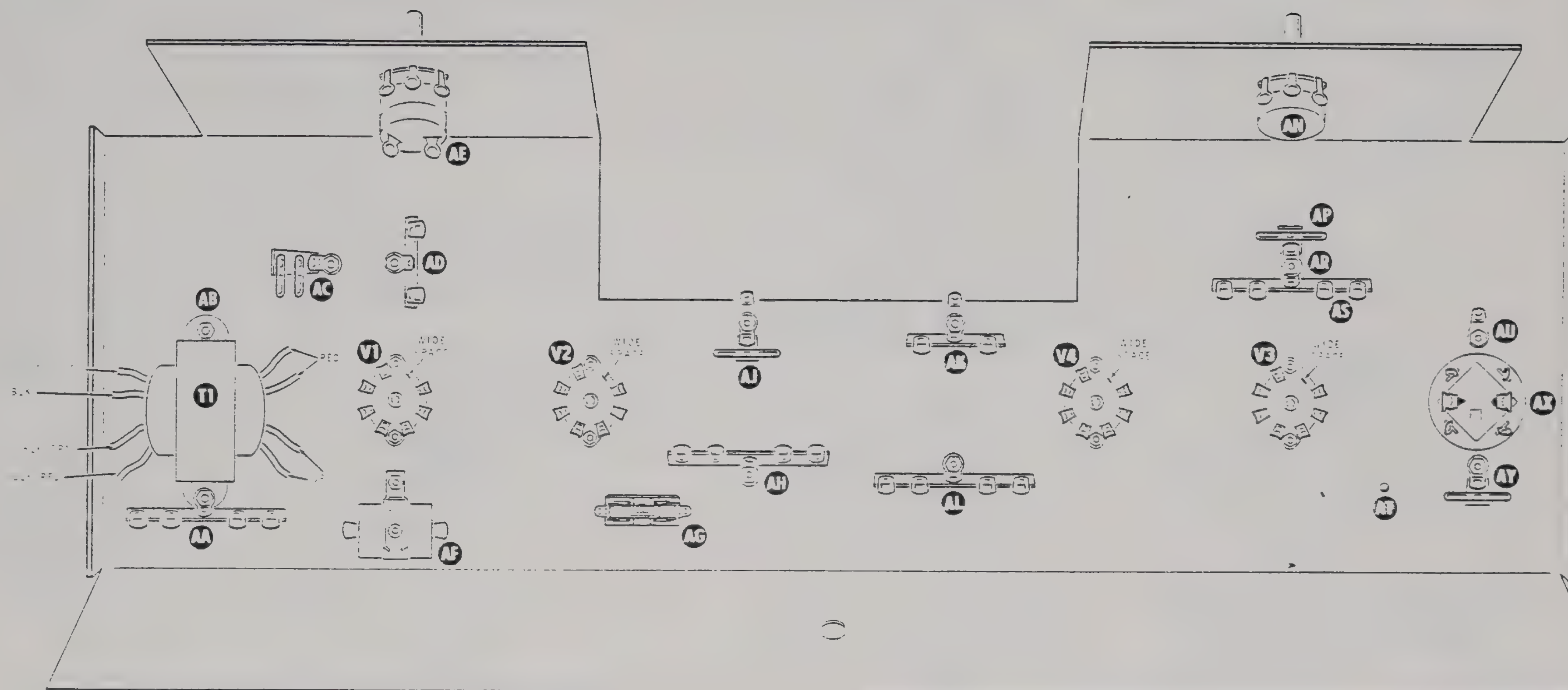
The prices apply only on purchases from the Heath Company where shipment is to a U.S.A. destination. Add 10% (minimum 25 cents) to the price when ordering from a Heathkit Electronic Center to cover local sales tax, postage, and handling. Outside the U.S.A., parts and service are available from your local Heathkit source and will reflect additional transportation, taxes, duties, and rates of exchange.

PARTS PICTORIAL (Cont'd.)



PARTS PICTORIAL





AE
AN
AP
AD
AR
AC
AB
AS
AU
V1
WIDE SPACE
V2
WIDE SPACE
AJ
AK
V4
WIDE SPACE
V3
WIDE SPACE
RED
BLK
T1
AX
AH
AL
AY
AA
AF
AG

PICTORIAL 1

ASSEMBLY NOTES

The illustrations in the next section of the Manual are called Pictorials and Details. Pictorials show the overall operation for a group of assembly steps. Details are used in addition to the Pictorials to illustrate a specific step. When you are directed to refer to a certain Pictorial "for the following steps," continue to use that Pictorial until you are directed to refer to another Pictorial.

A plastic nut starter is supplied with this kit to help you pick up and start nuts on screws. (See "Tools" in the "Kit Builders Guide.")

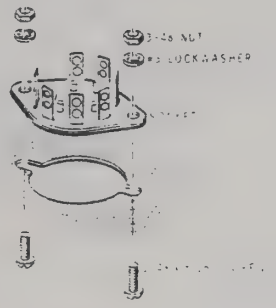
Use 1/2-watt resistors unless directed otherwise in a step. Resistors are identified by color code and resistance value in ohms (k = 1000, M = 1,000,000). Capacitors are identified by capacitance value in μF or pF, and type (disc, mica, electrolytic, etc.).

Before you start to assemble this kit, read the "Kit Builders Guide" for complete information on wiring, soldering, and step-by-step assembly procedures.

STEP-BY-STEP ASSEMBLY

Refer to Pictorial 1 (fold-out from Page 6) for the following steps.

NOTE: When hardware is called for in a step, only the screw size will be given. For instance, if "3-48 x 5/16" hardware" is called for, it means to use a 3-48 x 5/16" screw and a 3-48 nut. The Detail (or Pictorial) referred to in the step will show the type of screw to use and the proper number of lockwashers to use if they are needed.



Detail 1A

CHASSIS PARTS MOUNTING

( ) Refer to Detail 1A and, using 3-48 x 5/16" hardware, mount a 7-pin socket on the inside of the chassis at V1. Mount the socket so the wide space is positioned as shown in the Pictorial.

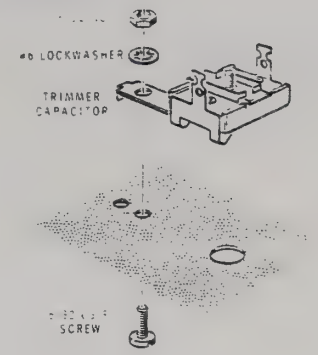
( ) In a like manner, mount 7-pin sockets at V2, V3, and V4, with 3-48 x 5/16" hardware.

NOTE: Do not use the two #6 external-tooth lockwashers until directed to do so in a step.

Detail 1B

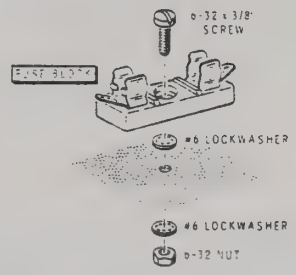
( ) Refer to Detail 1B and mount a 2-lug terminal strip (#431-2) at AD with 6-32 x 3/8" hardware. Position the terminal strip as shown in the Pictorial.

( ) In a similar manner, mount a 2-lug vertical-mount terminal strip (#431-51) at AC with 6-32 x 3/8" hardware. Position the terminal strip as shown in the Pictorial.



Detail 1C

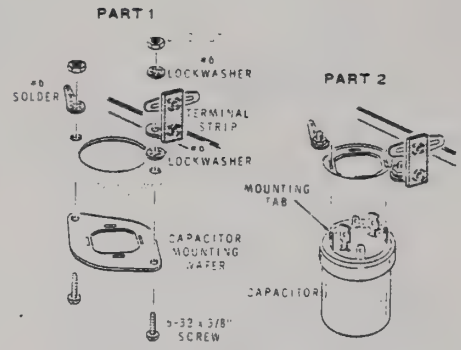
( ) Refer to Detail 1C and mount a trimmer capacitor at AF with 6-32 x 3/8" hardware. CAUTION: Be sure the tab on the trimmer mounting bracket is seated in the proper hole in the chassis before you tighten the screw.

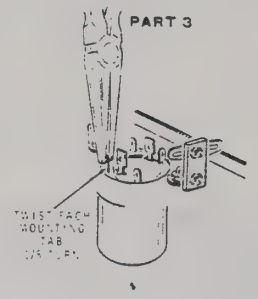


Detail 1D

( ) Refer to Detail 1D and mount a fuse block at AG with 6-32 x 3/8" hardware.

( ) Snap the 1/8-ampere, slow-blow fuse (supplied with this kit) into fuse block AG.

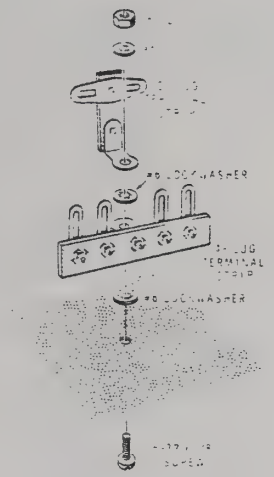




Detail 1E

( ) Refer to Part 1 of Detail 1E and, from the top of the chassis, mount a capacitor mounting wafer at AX with 6-32 x 3/8" hardware. Use a #6 solder lug at AU and a 1-lug terminal strip at AY. Position the solder lug and terminal strip as shown in the Pictorial.

( ) Refer to Part 2 of Detail 1E and mount a 1000-1000 μF electrolytic capacitor on the mounting wafer at AX. Position the capacitor with its lug markings as shown in the Pictorial; then twist the mounting tabs 1/8 turn as shown in Part 3.



Detail 1F

( ) Refer to Detail 1F and mount a 4-lug terminal strip and a 2-lug terminal strip at AR with 6-32 x 3/8" hardware. Position each terminal strip as shown in the Pictorial.

Refer to Detail 1G for the following steps.

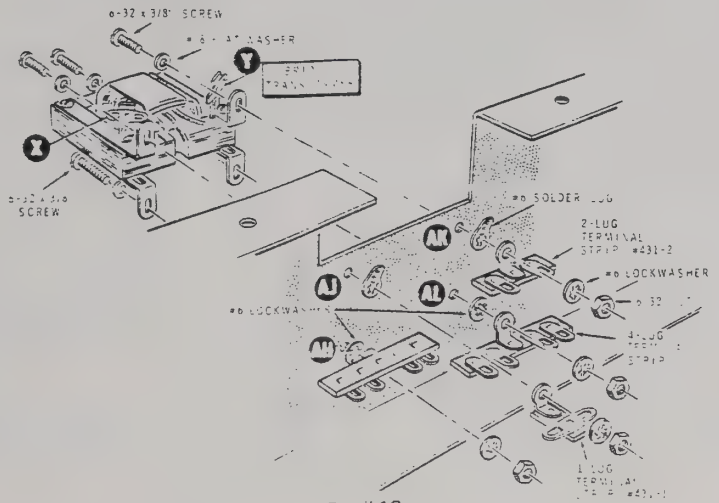
NOTE: In the following steps, you will mount the bridge transformer on the top of the chassis with four 6-32 screws. These screws are also used to mount terminal strips and solder lugs to the bottom of the chassis. Tighten the hardware only finger tight.

Secure the bridge transformer (#51-16) to the chassis top as follows:

( ) At AH and AL, use 6-32 x 3/8" screws, #8 flat washers, 4-lug terminal strips, #6 lockwashers, and 6-32 nuts.

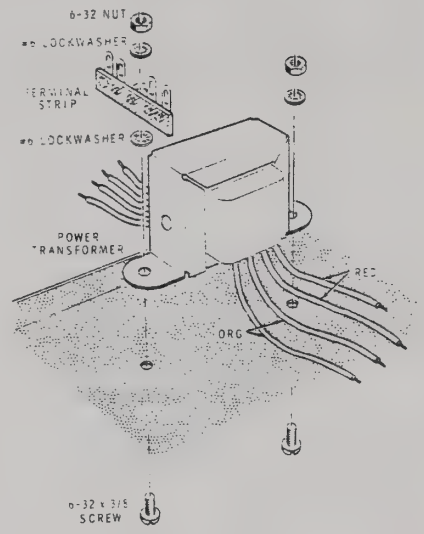
( ) At AJ, use a 6-32 x 3/8" screw, #8 flat washer, #6 solder lug, 1-lug terminal strip (#431-1), #6 lockwasher, and 6-32 nut.

( ) At AK, use a 6-32 x 3/8" screw, #8 flat washer, #6 solder lug, 2-lug terminal strip (#431-2), #6 lockwasher, and 6-32 nut.



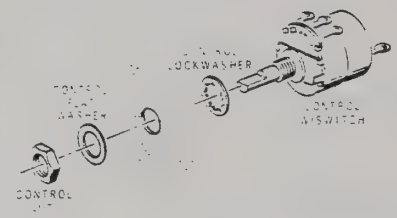
Detail 1G

( ) Position the terminal strips, and solder lugs, as shown in the Pictorial; then carefully tighten the hardware. CAUTION: Be very careful when you tighten the hardware at AJ and AK that you do not break the terminal strips already mounted on the bridge transformer.



Detail 1H

( ) Refer to Detail 1H and mount the power transformer (#54-56-24) at T1. Use a 6-32 x 3/8" screw, #6 lockwasher, and 6-32 nut at AB. Use a 6-32 x 3/8" screw, 4-lug terminal strip, #6 lockwasher, and 6-32 nut at AA.



Detail 1J

( ) Refer to Detail 1J and mount a 10 kΩ control with switch (#19-127) at AE. Position the control as shown in the Pictorial and tighten the control nut only finger tight.

( ) In a like manner install a 10 kΩ control (#10-262) at AN.

CHASSIS WIRING

NOTES:

1. The primary leads of the power transformer can be connected to operate from a 120 volt or 240 volt 50/60 Hz power source. In the U.S.A., 120 volts is most often used, while in other countries, 240 volts is more common. Use only the instructions that agree with the power line voltage in your area. For 240 volt wiring see Page 10 and Detail 2A.

2. In the following steps, (NS) means not to solder because other wires will be added later. "S-" with a number, such as (S-3) means to solder the connection. The number following the "S" tells how many wires are at the connection.

120 Volt Wiring

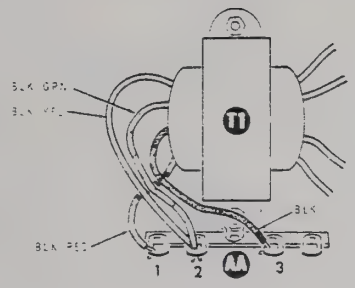
Refer to Pictorial 2 (fold-out from Page 11) and connect the primary leads of transformer T1 to terminal strip AA as follows. Be sure you make mechanically secure connections.

( ) Black-red to lug 1 (NS).

( ) Black-yellow to lug 1 (NS).

( ) Black-green to lug 3 (NS).

( ) Black to lug 3 (NS).



Detail 2A

240 Volt Wiring

Refer to Detail 2A and connect the primary leads of transformer T1 to terminal strip AA as follows. Be sure you make mechanically secure connections.

( ) Black-red to lug 1 (NS).

( ) Black-yellow to lug 2 (NS).

( ) Black-green to lug 2 (S-2).

( ) Black to lug 3 (NS).

Component Wiring

Refer to Pictorial 2 (fold-out from Page 11) for the following steps. Position the wires as shown in the Pictorial.

( ) Connect the short red transformer lead to lug 2 of terminal strip AC (NS).

( ) Connect the long red lead to lug 1 of terminal strip AJ (NS).

( ) Loosely twist together the orange leads coming from transformer T1.

( ) Connect one orange lead to lug 2 (NS) and the other orange lead to lug 3 (NS) of terminal strip AH.

( ) Press the orange and the red leads down against the chassis.

NOTE: Use the white insulated hookup wire when wire is called for in the following steps. Cut the wire to the proper length and remove 1/4" of insulation from each end unless directed otherwise in a step. Position each wire as shown in the Pictorial.

( ) Connect a 6-3/4" wire from lug 5 of switch AE (S-1) to lug 2 of fuse block AG (S-1).

( ) Connect a 16" wire from lug 7 of socket V2 (S-1) to lug 2 of capacitor AX (NS).

( ) Remove 1/4" of insulation from one end and 1" of insulation from the other end of a 3-1/2" wire.

NOTE: When a wire passes through a connection and then goes to another point, as in the next step, it will count as two wires in the solder instructions (S-2), one entering and one leaving the connection. Be sure these "through wires" are properly soldered to the connection.

( ) Insert the longer bare end of the 3-1/2" wire through lug 5 (S-2) to lug 1 (S-1) of socket V2. Connect the other end of the wire to lug 7 of socket V1 (S-1).

( ) Remove 1/4" of insulation from one end and 1" of insulation from the other end of a 5-1/2" wire.

( ) Insert the longer bare end of the 5-1/2" wire through lug 1 (NS) to lug 5 (NS) of socket V1. Connect the other end of the wire to lug 1 of control AE (S-1).

( ) Connect a 4" wire from lug 2 of terminal strip AD (NS) to lug 3 of socket V2 (NS).

( ) Connect a 4" wire from lug 1 of socket V1 (NS) to the solder lug at AJ (NS).

( ) Connect a 5" wire from lug 2 of control AE (S-1) to lug 6 of socket V2 (NS).

( ) Connect a 5-1/4" wire from lug 3 of socket V2 (NS) to lug 3 of terminal strip AL (NS).

( ) Connect a 2" wire from terminal 2 of terminal strip AJ (NS) to lug 1 of terminal strip AH (NS).

( ) Connect a 7-1/2" wire from terminal 2 of terminal strip AJ (NS) to lug 3 of terminal strip AS (NS).

( ) Remove 1/4" of insulation from one end and 1" of insulation from the other end of a 3-1/4" wire.

( ) Insert the longer bare end of the 3-1/4" wire through lug 5 (S-2) to lug 1 (NS) of socket V4. Connect the other end of the wire to the solder lug at AK (NS).

( ) Connect a 5" wire from lug 3 of terminal strip AL (NS) to lug 2 of terminal strip AS (NS).

( ) Connect a 3" wire from lug 2 of terminal strip AS (NS) to lug 3 of socket V3 (NS).

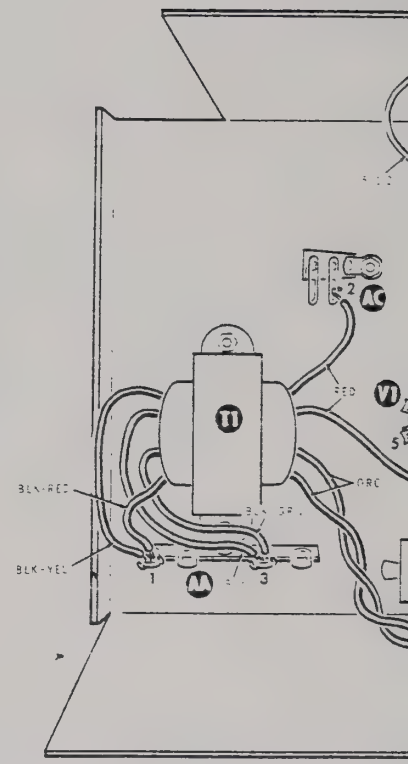
( ) Remove 1/4" of insulation from one end and 1" of insulation from the other end of a 3-3/4" wire.

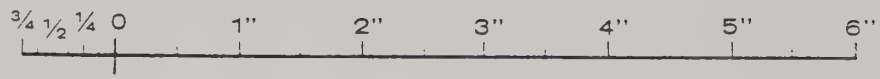
( ) Insert the longer bare end of the 3-3/4" wire through lug 5 (S-2) to lug 1 (S-1) of socket V3. Connect the other end of the wire to lug 7 of socket V4 (S-1).

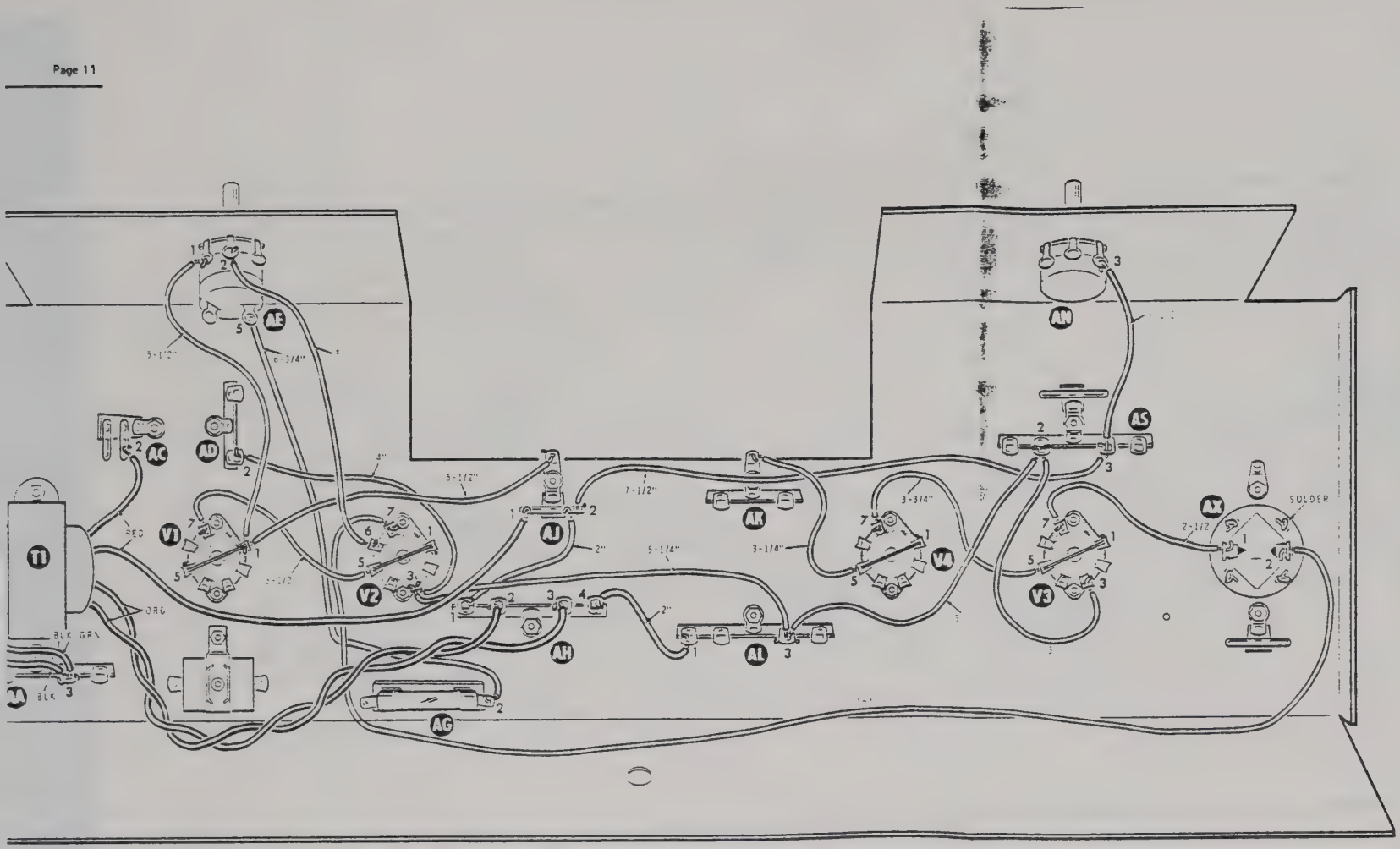
( ) Connect a 2-1/2" wire from lug 7 of socket V3 (S-1) to lug 1 of capacitor AX (NS).

( ) Connect a 3-1/2" wire from lug 3 of terminal strip AS (NS) to lug 3 of control AN (S-1).

( ) Connect a 2" wire from lug 4 of terminal strip AH (NS) to lug 1 of terminal strip AL (NS).

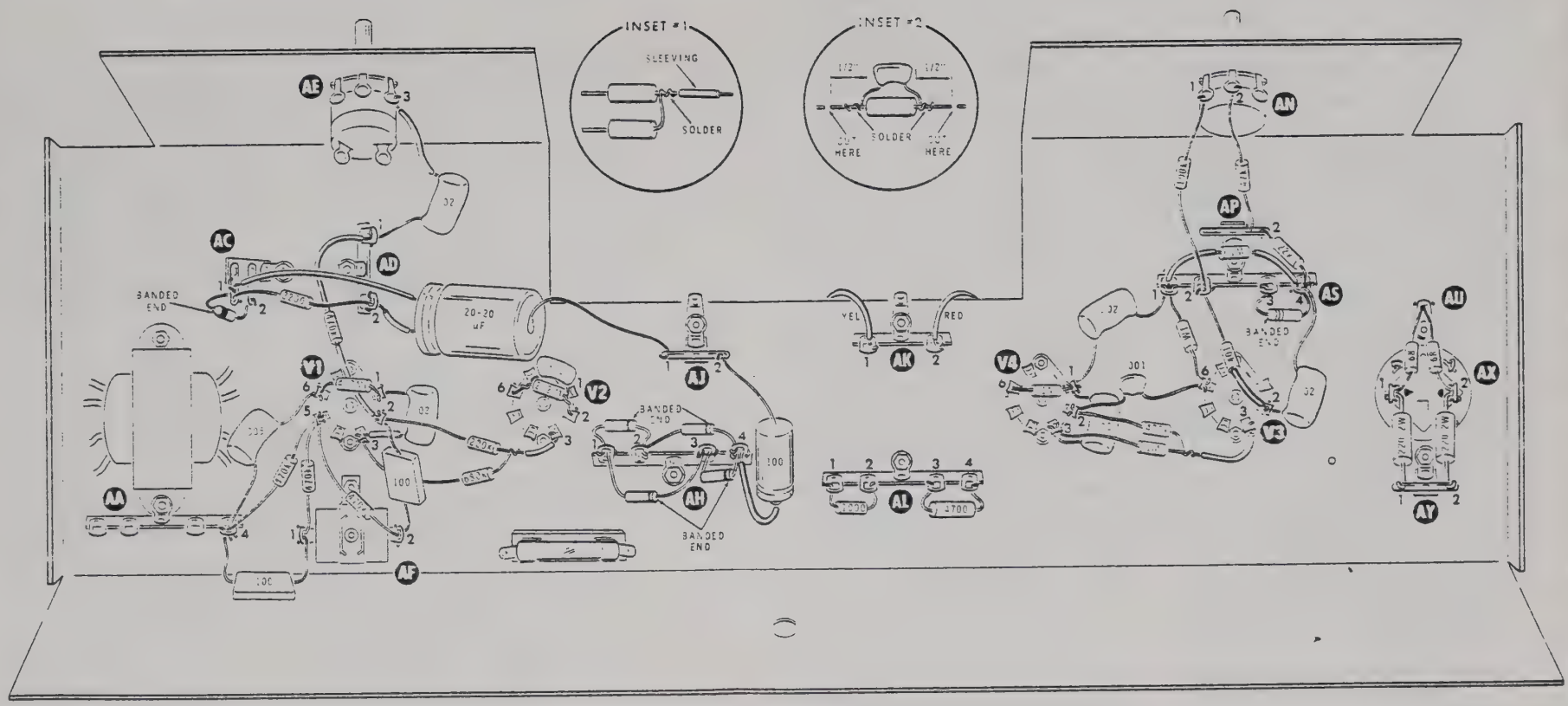






PICTORIAL 2

6"


INSET #1
SLEEVING
SOLDER
INSET #2
SOLDER
AE
AC
AD
AJ
AK
AP
AN
AS
AU
AX
AY
AM
AF
AH
AL
V1
V2
V3
V4
BANDED END
20-20 uF
YEL
RED

PICTORIAL 3

Refer to Pictorial 3 (fold-out from this Page) for the following steps.

NOTE: Unless directed otherwise, when you install a Mylar capacitor, disregard the position of the banded end. Also, straighten out the bends in the leads.

( ) Place 3/4" of sleeving on one lead of a .02 μF Mylar capacitor; then connect the lead to lug 3 of control AE (S-1). Connect the other lead to lug 1 of terminal strip AD (NS).

( ) Place a 3/4" length of sleeving on each lead of a 470 kΩ (yellow-violet-yellow) resistor. Connect one lead to lug 1 of terminal strip AD (S-2) and the other lead to lug 2 of socket V1 (NS).

NOTE: When you install the diode in the following step, be sure to connect the lead at the banded end as shown in the Pictorial.

( ) Connect the lead at the banded end of a silicon diode (#57-27) to lug 1 of terminal strip AC (NS). Connect the other lead to lug 2 of terminal strip AC (NS).

( ) Connect a 2200 Ω (red-red-red) resistor from lug 1 of terminal strip AC (NS) to lug 2 of terminal strip AD (NS).

NOTE: In the following steps, be sure to connect the two leads at the positive (+) marked end of the 20-20 μF electrolytic capacitor as shown in the Pictorial.

( ) Place a 1/2" length of sleeving on one lead at the positive (+) marked end of a 20-20 μF electrolytic capacitor. Then connect this lead to lug 2 of terminal strip AD (S-3).

( ) Place a 1-3/8" length of sleeving on the other positive lead of the capacitor and connect it to lug 1 of terminal strip AC (S-3).

( ) Connect the lead at the other end of the 20-20 μF electrolytic capacitor to terminal 1 of terminal strip AJ (NS).

( ) Cut both leads of a 4.7 MΩ (yellow-violet-green) resistor to 1/2". Then connect this resistor between lugs 1 (NS) and 6 (NS) of socket V1. NOTE: Position the body of the resistor up and away from the tube socket.

( ) Connect a 470 kΩ (yellow-violet-yellow) resistor from lug 5 of socket V1 (NS) to lug 4 of terminal strip AA (NS).

( ) Connect a 470 kΩ (yellow-violet-yellow) resistor from lug 5 of socket V1 (NS) to lug 1 of trimmer capacitor AF (NS).

( ) Connect a 470 kΩ (yellow-violet-yellow) resistor from lug 5 of socket V1 (S-4) to lug 2 of trimmer capacitor AF (NS).

( ) Connect a .005 μF Mylar capacitor from lug 6 of socket V1 (S-2) to lug 4 of terminal strip AA (NS).

( ) Connect a 100 pF mica capacitor from lug 4 of terminal strip AA (S-3) to lug 1 of trimmer capacitor AF (S-2).

( ) Place a 1/2" length of sleeving on one lead of a .02 μF Mylar capacitor. Connect this lead to lug 3 of socket V1 (NS). Connect the other lead to lug 1 of socket V1 (S-5). NOTE: Be sure all five leads are properly soldered to lug 1.

( ) Refer to inset drawing #1 on Pictorial 3 and, using a 220 kΩ (red-red-yellow) resistor and a 680 kΩ (blue-gray-yellow) resistor, prepare a 2-resistor combination. Place a 1/2" length of sleeving on the lead at the prepared end as shown.

( ) Connect the lead at the prepared end to lug 3 of socket V2 (S-3).

( ) Connect the free lead of the 220 kΩ (red-red-yellow) resistor to lug 2 of socket V1 (NS).

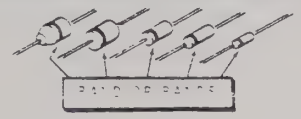
( ) Connect the free lead of the 680 kΩ (blue-gray-yellow) resistor to lug 3 of socket V1 (S-2).

( ) Connect a 100 pF mica capacitor from lug 2 of socket V1 (S-3) to lug 2 of trimmer capacitor AF (S-2).

( ) Refer to inset drawing #2 on Pictorial 3 and, using a 2.2 MΩ (red-red-green) resistor and 310 pF mica capacitor, prepare a resistor-capacitor combination as shown.

( ) Connect the resistor-capacitor combination between lugs 6 (S-2) and 2 (NS) of socket V2. NOTE: The resistor-capacitor combination should be spaced approximately 1/4" above the socket lugs.

NOTE: DIODES MAY BE SUPPLIED IN ANY OF THE FOLLOWING SHAPES. ALWAYS POSITION THE BANDED END AS SHOWN ON THE PICTORIAL.



Four 1N4002 silicon diodes (#57-65) will be mounted on terminal strip AH in the following steps.

( ) Connect the lead at the banded end of a 1N4002 diode to lug 4 of terminal strip AH (NS). Connect the other lead to lug 3 of the terminal strip (NS).

( ) Connect the lead at the banded end of a 1N4002 diode to lug 3 of terminal strip AH (S-3). Connect the other lead to lug 1 of the terminal strip (NS).

( ) Connect the lead at the banded end of a 1N4002 diode to lug 4 of terminal strip AH (NS). Connect the other lead to lug 2 of the terminal strip (NS).

( ) Connect the lead at the banded end of a 1N4002 diode to lug 2 of terminal strip AH (S-3). Connect the other lead to lug 1 of the terminal strip (S-3).

( ) Place 1" of sleeving on the lead at the positive (+) end of a 100 μF electrolytic capacitor. Then connect this lead to lug 4 of terminal strip AH (S-4). Connect the other lead to terminal 2 of terminal strip AJ (NS).

( ) Connect a 1000 Ω (brown-black-red) resistor between lug 1 (NS) and lug 2 (NS) of terminal strip AL.

( ) Connect a 4700 Ω, 1-watt (yellow-violet-red) resistor between lugs 3 (NS) and 4 (NS) of terminal strip AL.

( ) Cut both leads of a 1 MΩ (brown-black-green) resistor to 1/2". Then connect this resistor between lugs 6 (NS) and 1 (NS) of socket V4.

( ) Connect a .02 μF Mylar capacitor from lug 1 of socket V4 (NS) to lug 1 of terminal strip AS (NS).

( ) Connect a .02 μF Mylar capacitor between lugs 1 (S-4) and 3 (NS) of socket V4.

( ) Refer to inset drawing #1 on Pictorial 3 and, using a 470 kΩ (yellow-violet-yellow) resistor and a 1 MΩ (brown-black-green) resistor, prepare a two-resistor combination. Place a 1/2" length of sleeving on the lead at the prepared end as shown.

( ) Connect the lead at the prepared end of the combination to lug 3 of socket V3 (S-2).

( ) Connect the free lead of the 470 kΩ (yellow-violet-yellow) resistor to lug 2 of socket V4 (NS).

( ) Connect the free lead of the 1 MΩ (brown-black-green) resistor to lug 3 of socket V4 (S-2).

( ) Connect a .001 μF disc capacitor from lug 2 of socket V4 (S-2) to lug 6 of socket V3 (NS).

( ) Connect a 1 MΩ (brown-black-green) resistor from lug 6 of socket V3 (S-2) to lug 1 of terminal strip AS (NS).

( ) Place a 1/2" length of sleeving on each lead of a 1 MΩ (brown-black-green) resistor.

( ) Connect this resistor between lugs 1 (S-3) and 4 (NS) of terminal strip AS.

( ) Connect a 100 kΩ (brown-black-yellow) resistor from lug 1 of control AN (S-1) to lug 2 of terminal strip AS (NS).

( ) Place a 3/4" length of sleeving on one lead of a 10 kΩ (brown-black-orange) resistor. Connect this lead to lug 2 of socket V3 (NS). Connect the other lead to lug 2 of terminal strip AS (S-4).

( ) Connect a .02 μF Mylar capacitor from lug 2 of socket V3 (S-2) to lug 4 of terminal strip AS (NS).

( ) Connect a 22 kΩ (red-red-orange) resistor from lug 4 of terminal strip AS (NS) to terminal 2 of terminal strip AP (NS).

NOTE: Glass diodes can be easily broken by bending the leads too close to the ends of the diode. Therefore, in the next step bend the leads at least 1/8" away from the ends of the diode.

( ) Connect the lead at the banded end of a 1N191 (brown-white-brown) diode to lug 3 of terminal strip AS (S-3). Connect the other lead of the diode to lug 4 of terminal strip AS (S-4).

( ) Connect a 47 kΩ (yellow-violet-orange) resistor from terminal 2 of terminal strip AP (S-2) to lug 2 of control AN (S-1).

( ) Connect a 68 Ω (blue-gray-black) resistor from solder lug AU (NS) to lug 1 of capacitor AX (NS).

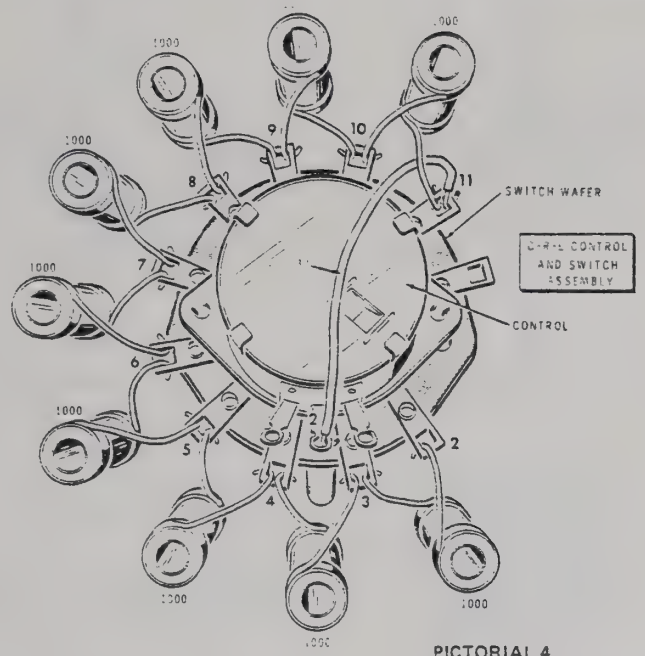
( ) Connect a 68 Ω (blue-gray-black) resistor from solder lug AU (NS) to lug 2 of capacitor AX (NS).

( ) Connect a 220 Ω, 2-watt (red-red-brown) resistor from lug 1 of capacitor AX (S-3) to terminal 1 of terminal strip AY (NS).

( ) Connect a 220 Ω, 2-watt (red-red-brown) resistor from lug 2 of capacitor AX (S-3) to terminal 2 of terminal strip AY (S-1).

( ) Connect the red lead coming from the bridge transformer to lug 2 of terminal strip AK (NS).

( ) Connect the yellow lead coming from the bridge transformer to lug 1 of terminal strip AK (NS). The blue lead will be connected later.



PICTORIAL 4

Control and Switch Wiring

Refer to Pictorial 4 for the following steps.

( ) Locate the 1250 Ω control with 10-position switch #19-36.

( ) Connect a 3" hookup wire from lug 2 of the control (S-1) to lug 11 of the switch (NS).

( ) Locate the nine 1000 Ω (1 k), precision resistors and cut both leads of each resistor to 3/4".

( ) Form both leads of each resistor as shown in the Pictorial.

Connect the prepared 1000 Ω precision resistors between the lugs of the switch wafer as follows. Position the resistors as shown.

( ) Between lugs 11 (S-2) and 10 (NS).

( ) Betwen lugs 10 (S-2) and 9 (NS).

( ) Between lugs 9 (S-2) and 8 (NS).

( ) Between lugs 8 (S-2) and 7 (NS).

( ) Between lugs 7 (S-2) and 6 (NS).

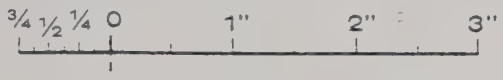
( ) Between lugs 6 (S-2) and 5 (NS).

( ) Between lugs 5 (S-2) and 4 (NS).

( ) Between lugs 4 (S-2) and 3 (NS).

( ) Between lugs 3 (S-2) and 2 (S-1).

Set this C-R-L Control and Switch Assembly aside until it is called for in a step



( ) Locate the 550 Ω, precision resistor and set it aside until it is called for in the "Test and Adjustment" section of this Manual.

( ) Cut both leads of each of the remaining (9) precision resistors to 3/4".

Refer to Pictorial 5 and mount the precision resistors on the wafers of 8-position, 2-section switch #63-514. Position each resistor as shown in the Pictorial.

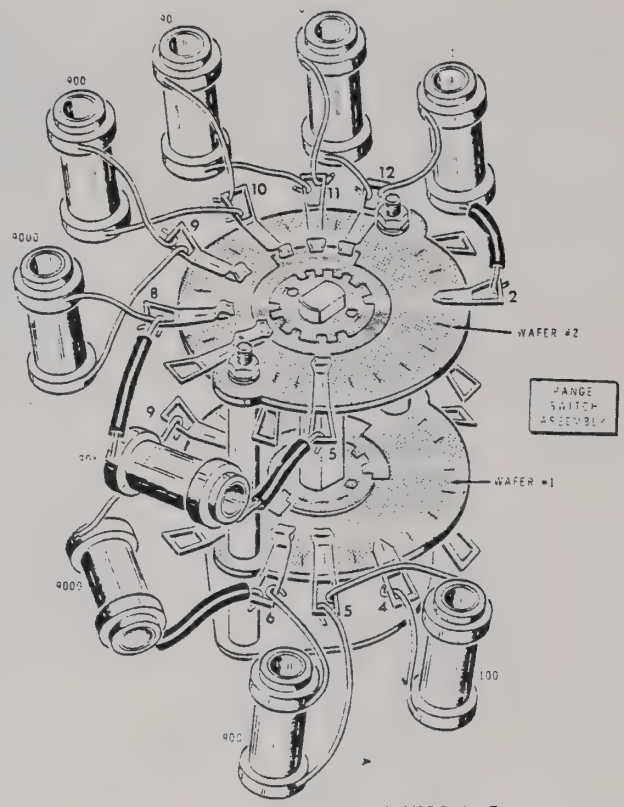
( ) Place 1/2" lengths of sleeving on both leads of a 90 kΩ, precision resistor. Connect one lead to lug 5 of wafer 2 (S-1) and the other lead to lug 8 of wafer 2 (NS).

( ) Place 1/2" of sleeving on one lead of a 9000 Ω (9 K), precision resistor. Connect this lead to lug 6 of wafer 1 (NS) and the other lead to lug 9 of wafer 1 (S-1).

( ) Form both leads of the remaining precision resistors as shown in the Pictorial.

Connect the following precision resistors between the lugs on wafer 1 of the switch.

( ) 900 Ω resistor between lugs 6 (S-2) and 5 (NS).



PICTORIAL 5

( ) 100 Ω resistor between lugs 5 (S-2) and 4 (NS).

Connect the following precision resistors between the lugs on wafer 2 of the switch.

( ) 9000 Ω (9 K), resistor between lugs 8 (S-2) and 9 (NS).

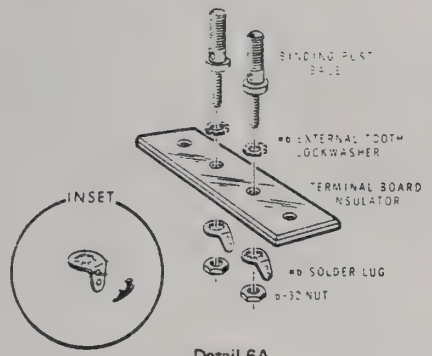
( ) 900 Ω resistor between lugs 9 (S-2) and 10 (NS).

( ) 90 Ω resistor between lugs 10 (S-2) and 11 (NS).

( ) 9 Ω resistor between lugs 11 (S-2) and 12 (NS).

( ) Place 1/2" of sleeving on one lead of the 1 Ω resistor. Connect this lead to lug 2 (NS) and the other lead to lug 12 (S-2).

Set the switch assembly aside until it is called for in a step.



Detail 6A

PANEL PARTS MOUNTING

Refer to Pictorial 6 (fold-out from Page 17) for the following steps.

( ) Locate two #6 solder lugs. Then bend both lugs to an angle of 90 degrees as shown in the inset drawing on Detail 6A.

( ) Refer to Detail 6A and mount binding post bases in the two indicated holes in the terminal board insulator. Be sure the larger portion of each binding post base is on the beveled side of the insulator.

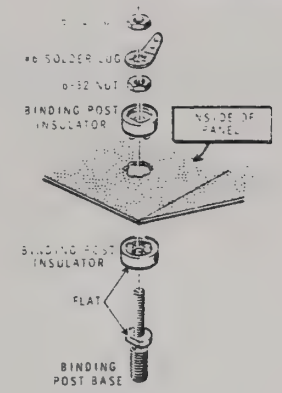
( ) Mount the binding post assembly at BC with 6-32 x 3/8" hardware. Be sure the solder lugs are positioned as shown in the Pictorial.

( ) Refer to Detail 6B and install binding post bases at BG1 and BG2. Be sure the hole through each base is positioned as shown in the Detail and that the solder lugs are positioned as shown in the Pictorial.

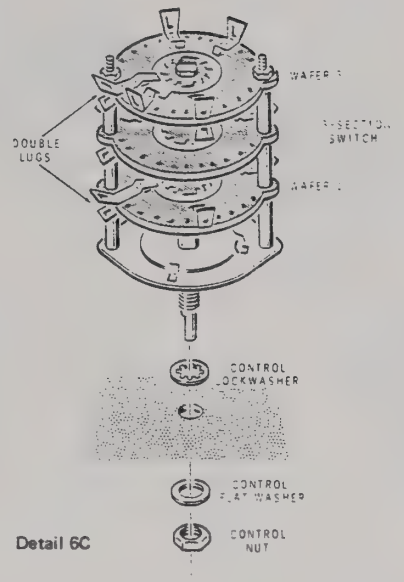
( ) In a like manner, install binding post bases at BL1 and BL2.

( ) Refer to Detail 6C and mount 5-position, 3-section switch #63-515 at BE. CAUTION: Be sure you mount the switch so the double lugs on wafers 1 and 3 are positioned as shown in the Pictorial.

( ) In a similar manner, mount 4-position, 2-section switch #63-513 at BK. Position the switch as shown in the Pictorial. NOTE: This is a symmetrical switch, so either group of lugs may be positioned upward.

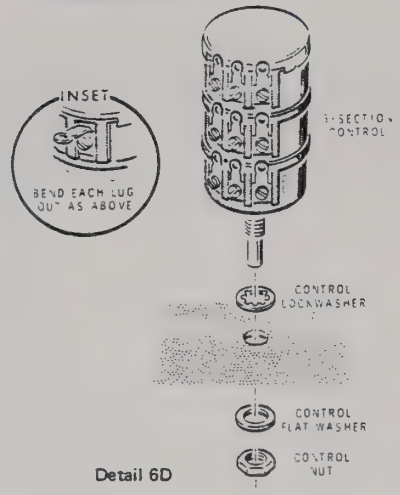


Detail 6B



Detail 6C

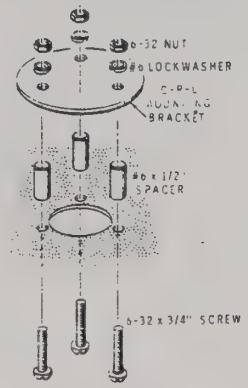
( ) Mount 4-position, spring-loaded switch #63-512 at BH. Position the switch so the spring is positioned as shown.



Detail 6D

( ) Refer to Detail 6D and mount the 165Ω/1600 Ω/16 kΩ, 3-section control at BF. NOTE: Bend each lug out as shown in the inset drawing.

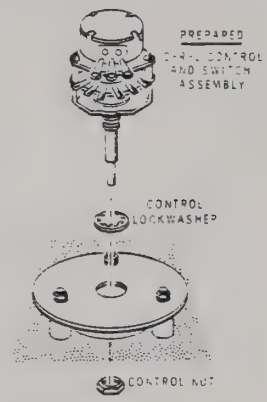
( ) Mount the previously prepared 8-position, 2-section switch assembly (#63-514) at BB. Position the switch as shown in the Pictorial.



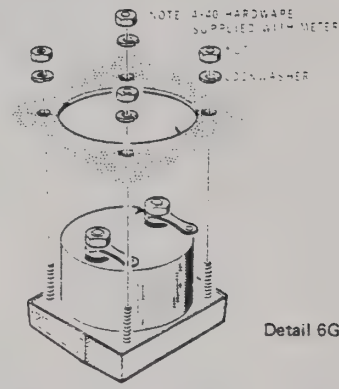
Detail 6E

( ) Refer to Detail 6E and install the C-R-L mounting bracket at BA.

( ) Refer to Detail 6F and mount the prepared C-R-L Control and Switch Assembly on the C-R-L mounting bracket at BA. Do not use a control flat washer. Position the assembly as shown in the Pictorial.



Detail 6F



Detail 6G

( ) Refer to Detail 6G and, using the hardware in the meter carton, mount the meter at BD. Do not overtighten the hardware. NOTE: If you wish, secure the foam sheet or a piece of cardboard over the meter to protect the meter face.

( ) Remove any wire or clip that may be connected between the meter posts

R-L mounting

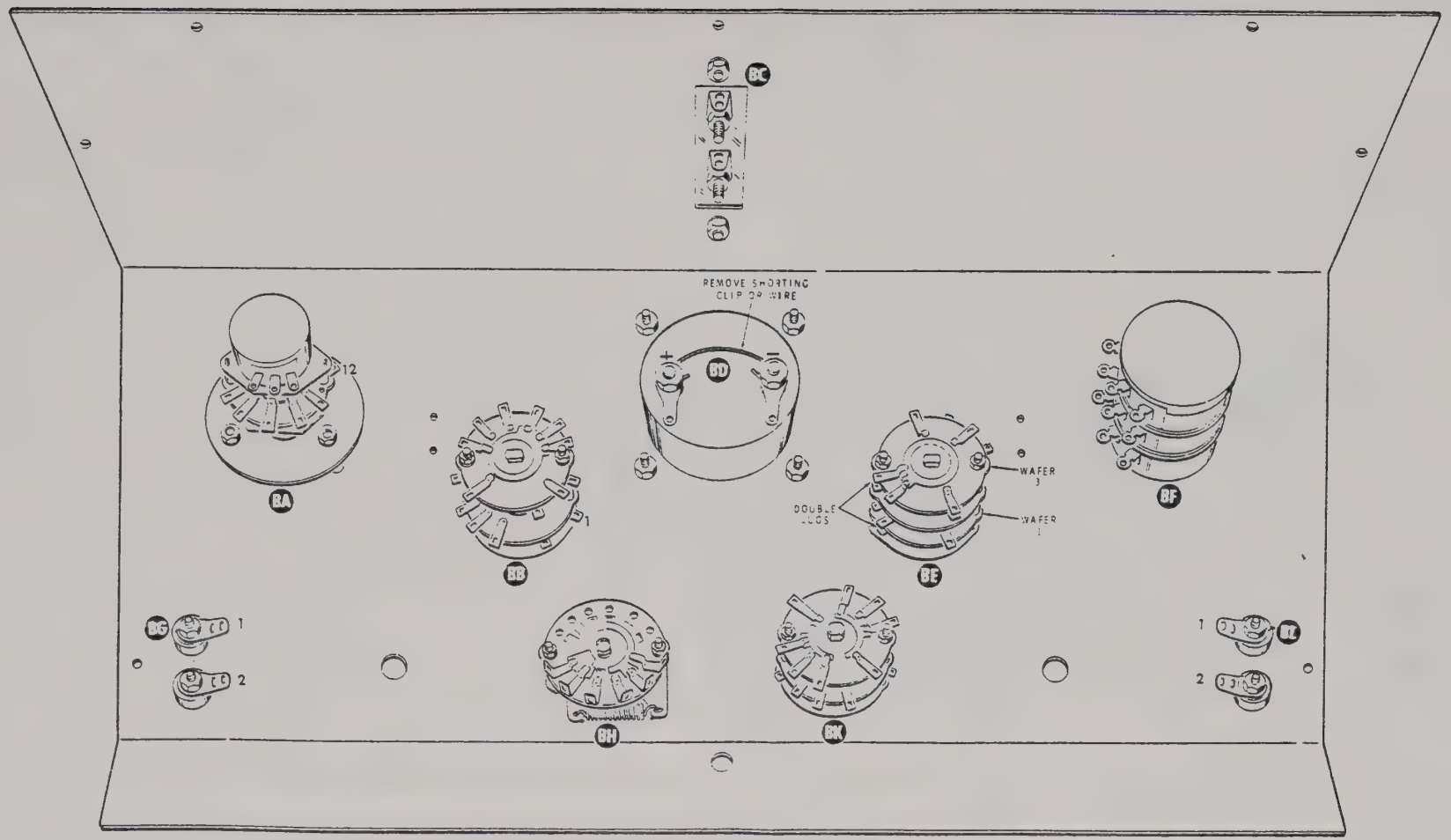
repared C-R-L
R-L mounting
l flat washer.
ctorial.

Detail 6F

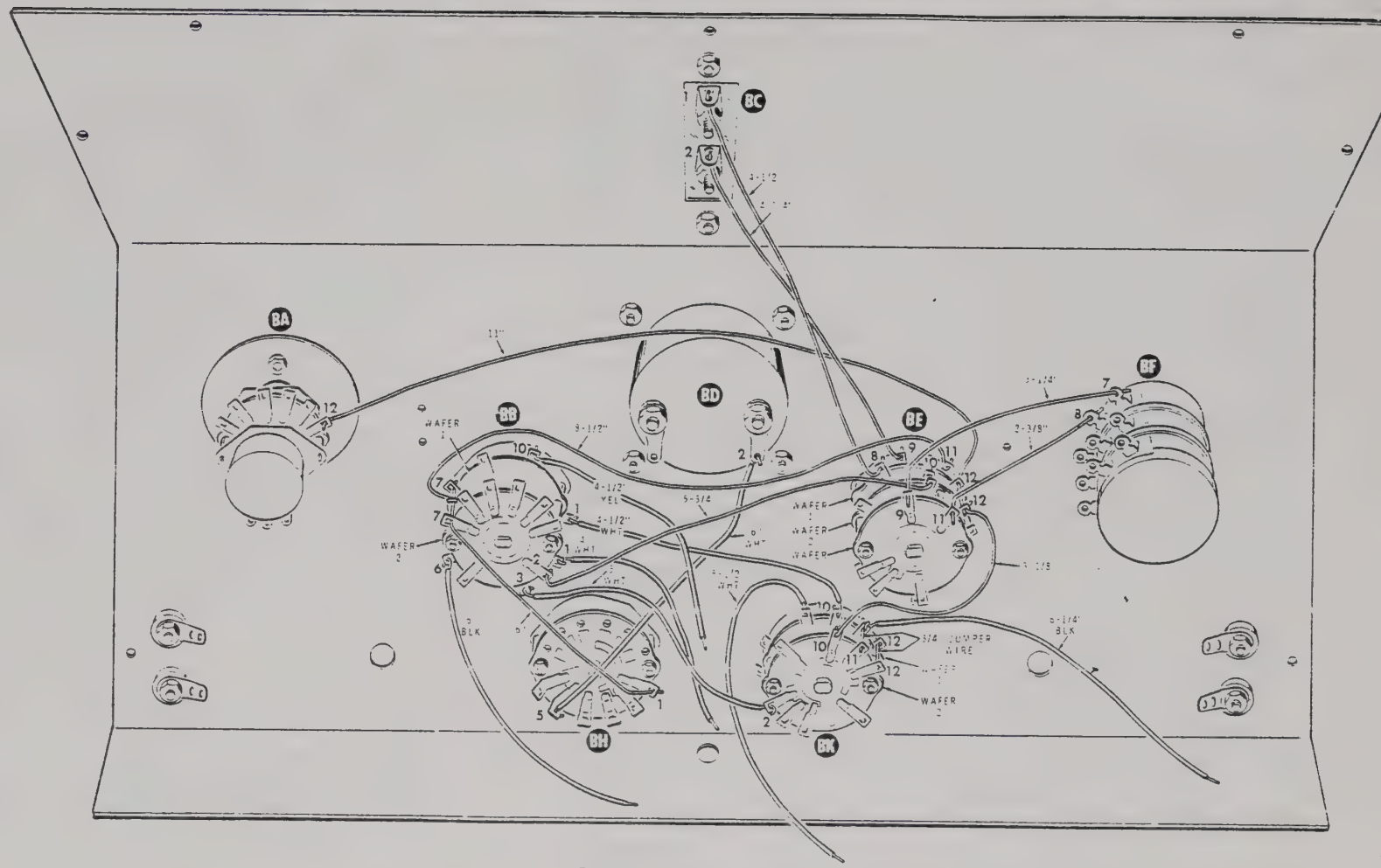
Detail 6G

rdware in the
BD. Do not
u wish, secure
over the meter

be connected



PICTORIAL 6


BA
BB
BC
BD
BE
BF
BG
BH
WAFER 1
WAFER 2
WAFER 3
WAFER 1
WAFER 2
WAFER 3
11"
3-1/2"
4-1/2" YEL
5-1/2" WHT
5-3/4
2-3/8"
3/4 JUMPER WIRE
BLK

PICTORIAL 7

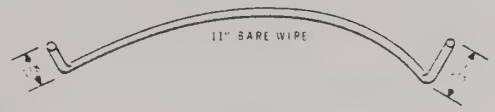
PANEL WIRING

Heavy bare wire will be used for most of the wiring between the switches on the panel which will result in minimum wiring resistance. Due to this open and rigid style of wiring, the capacitance of the wiring is held to a minimum.

Before you start to wire the panel, place one end of the heavy bare wire in a vise. Then using a pair of pliers, pull on the other end of the wire until it stretches slightly. This will remove the kinks, stiffen the wire, and will result in better and neater wiring.

Proceed carefully, as once a heavy wire is connected to a switch lug, it is difficult to change the connection without damaging the lug. Cut each wire to the length specified. Then form it so a minimum amount of bending will be required after the wire is connected to (or inserted through) one or more switch lugs.

Refer to Pictorial 7 (fold-out from Page 18) for the following steps. Use heavy bare wire unless directed otherwise in a step.



Detail 7A

NOTES:

1. As an example, Detail 7A shows the length and the angle of the bend at each end of the first bare wire that you will install in the following steps. The initial forming of this wire which must be done prior to installation is also shown. Each heavy bare wire should be formed as necessary so it will fit before it is soldered in place. The length of bare wire will be indicated in the step along with any special bending instructions.

2. Maintain approximately 1/4" of space where a bare wire passes over a switch wafer or past any metal object or other bare wire.

FOR GOOD SOLDERED CONNECTIONS, YOU MUST KEEP THE SOLDERING IRON TIP CLEAN...
WIPE IT OFTEN WITH A DAMP SPONGE OR CLOTH.

( ) Prepare an 11" bare wire by making a 1/8" bend in one end and a 5/8" bend in the other end. Make both bends in the same direction.

( ) Insert the 5/8" bend of the wire up through lug 12 on wafer 1 (S-2) to lug 12 on wafer 2 (NS) of switch BE.

( ) Carefully form the wire around meter BD and connect the free end to lug 12 of switch BA (S-1).

( ) Connect a 6" white wire from lug 2 of meter BD (S-1) to lug 5 of switch BH (S-1).

( ) Prepare a 6" bare wire by making a 1-1/2" bend at one end. Then insert the 1-1/2" bend down through lug 7 on wafer 2 (S-2) to lug 7 on wafer 1 (S-1) of switch BB.

( ) Connect the other end of this wire to lug 1 of switch BH (S-1). NOTE: Do not shorten this wire as it must be formed later on, after the panel is mounted to the chassis.

( ) Prepare an 8-1/2" bare wire by making a 1/8" bend at one end and a small hook in the other end.

( ) Connect the hooked end around the wire at lug 7 on wafer 1 of switch BB (S-1). Connect the other end to lug 11 on wafer 1 of switch BE (S-1).

( ) Connect a 4-1/2" white wire from lug 1 on wafer 1 of switch BB (S-1) to lug 10 on wafer 1 of switch BK (S-1).

( ) Connect one end of a 4-1/2" yellow wire to lug 10 on wafer 1 of switch BB (S-1). The other end will be connected later.

( ) Connect one end of a 6" black wire to lug 6 on wafer 2 of switch BB (S-1). The other wire will be connected later.

( ) Connect a 5" white wire from lug 3 on wafer 2 of switch BB (S-1) to lug 6 on wafer 2 of switch BK (S-1).

( ) Connect one end of a 4" white wire to lug 1 on wafer 2 of switch BB (S-1). The other end will be connected later.

( ) Connect a 4-1/4" bare wire from lug 2 of binding post assembly BC (S-1) to lug 9 on wafer 1 of switch BE (S-1).

( ) Connect a 4-1/2" bare wire from lug 1 of binding post assembly BC (S-1) to lug 8 on wafer 1 of switch BE (S-1).

( ) Prepare a 5-3/4" bare wire by making a 1/8" bend at one end and a 1/4" bend at the other end. Make both bends in the same direction.

( ) Connect the end of the wire with the 1/4" bend to double lug 10 on wafer 2 of switch BE (S-2). Connect the other end of the wire to lug 2 on wafer 2 of switch BB (S-2).

( ) Connect a 2-3/8" bare wire from lug 8 of control BF (S-1) to lug 11 on wafer 3 of switch BE (NS).

( ) Prepare a 3-1/4" bare wire by making a 1/8" bend at each end of the wire.

( ) Connect one end of the wire to lug 9 on wafer 3 of switch BE (S-1). Connect the other end of the wire to lug 7 of control BF (S-1).

( ) Make a 1/2" bend in one end of a 3-1/8" bare wire.

( ) Connect the end of the wire with the 1/2" bend to lug 12 on wafer 2 of switch BE (S-2).

( ) Connect the other end of the wire to lug 10 on wafer 2 of switch BK (S-1).

( ) Connect one end of a 5-1/2" white wire to lug 9 on wafer 1 of switch BK (S-1). The other end will be connected later.

( ) Remove the insulation from a 3/4" length of white wire. Then connect this wire from lug 11 on wafer 1 of switch BK (NS) to lug 11 on wafer 2 of switch BK (NS).

( ) Connect one end of a 6-1/4" black wire to lug 11 on wafer 1 of switch BK (S-2). The other end will be connected later.

( ) Remove the insulation from a 3/4" length of white wire. Connect this wire from lug 12 on wafer 1 of switch BK (S-1) to lug 12 on wafer 2 of switch BK (NS).

Refer to Pictorial 8 (fold-out from Page 21) for the following steps.

( ) Connect one end of a 4" red wire to lug 3 on wafer 1 of switch BB (S-1). The other end will be connected later.

( ) Prepare a 5-5/8" bare wire by making a 1/8" bend at one end and a 1/2" bend at the other end.

( ) Connect the end of the wire with the 1/2" bend to lug 4 on wafer 1 of switch BB (S-2). Connect the other end to lug 7 on wafer 2 of switch BE (S-1).

( ) Use pliers to securely hold the #1 solder lug on meter BD so it cannot turn; then loosen the nut that secures the lug. NOTE: If the meter post should turn slightly, remove the loosened nut and solder lug; then very carefully tighten the other nut on the meter post.

( ) Position the #1 solder lug as shown in Pictorial 8 and carefully tighten the nut. Then bend the lug straight up and away from the meter.

( ) Make a 1/8" bend at one end of a 10-1/2" bare wire. Thread the bent end through lug 1 of meter BD (NS) and on to lug 3 on wafer 1 of switch BE (NS). Now solder the bare wire in solder lug 1 of meter BD (S-2).

( ) Connect the free end of the bare wire to lug 3 of control BA (S-1). Form the wire so it will clear the case of the control and the resistors on switch BB.

( ) Place 3/4" lengths of sleeving on the leads of a .1 μF (100,000 pF) mica capacitor.

( ) Connect one capacitor lead to lug 11 on wafer 3 of switch BE (S-2). Connect the other lead to lug 3 on wafer 1 of switch BE (S-2).

( ) Connect a 1" bare wire from lug 5 (S-1) to lug 2 (NS) of control BF.

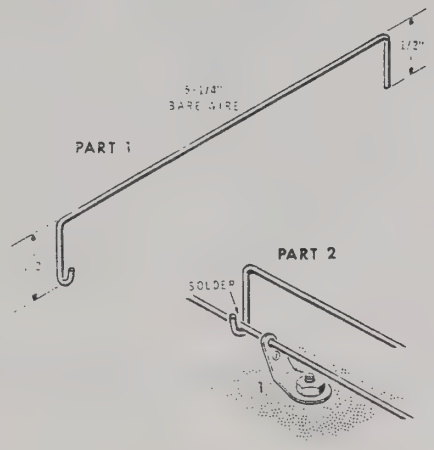
( ) Make a 1/8" bend at one end of a 2" bare wire. Insert the bent end through lug 12 on wafer 3 of switch BE (NS).

( ) Place the other end of this bare wire against lug 2 of control BF; then solder the wire to the control (S-2).

Refer to Detail 8A for the next two steps.

( ) Make a small hook at one end of a 5-1/4" bare wire. Then bend each end as shown in Part 1 of the Detail.

( ) Connect the hooked end of the wire around the wire through lug 1 of meter BD (S-1) as shown in Part 2 of the Detail.



Detail 8A

( ) Connect the other end of the wire to lug 10 on wafer 3 of switch BE (NS).

( ) Place 3/4" lengths of sleeving on the leads of a .01 μF (10,000 pF) mica capacitor.

( ) Connect one capacitor lead to lug 12 (S-2) and the other lead to lug 10 (S-2) on wafer 3 of switch BE. Position the capacitor as shown in the Pictorial.

( ) Prepare a 4" bare wire by making a 3/8" bend at one end and a 1/8" bend at the other end. Make both bends in the same direction.

( ) Connect the end of the wire with the 3/8" bend to lug 5 on wafer 3 of switch BE (S-1). Connect the other end to lug 6 of control BF (S-1).

( ) Prepare a 3" bare wire by making a 3/8" bend at one end and a 1/8" bend at the other end.

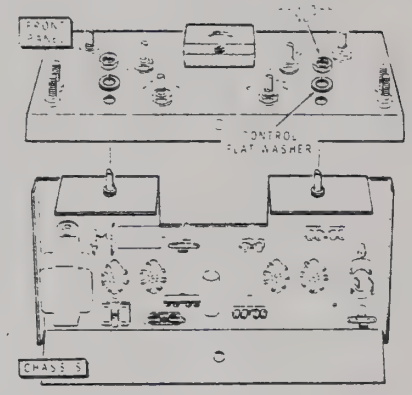
( ) Connect the end of the wire with the 3/8" bend to double-lug 3 on wafer 3 of switch BE (S-2). Connect the other end to lug 3 of control BF (S-1).

( ) Prepare a 4-1/4" bare wire by making a 1-1/4" bend at one end and a 1/4" bend at the other end. Make both bends in the same direction.

( ) Very carefully insert the end of the wire with the 1-1/4" bend down through double-lug 6 on wafer 3, then through lug 6 on wafer 2, and on through double-lug 6 on wafer 1 of switch BE.

( ) Connect the other end of the wire to lug 4 on wafer 2 of switch BK (S-1).

( ) Now solder the wire where it passes through the lugs on wafers 1, 2, and 3 of switch BE. NOTE: Do not allow the solder to flow down into the switch contacts.



PICTORIAL 9

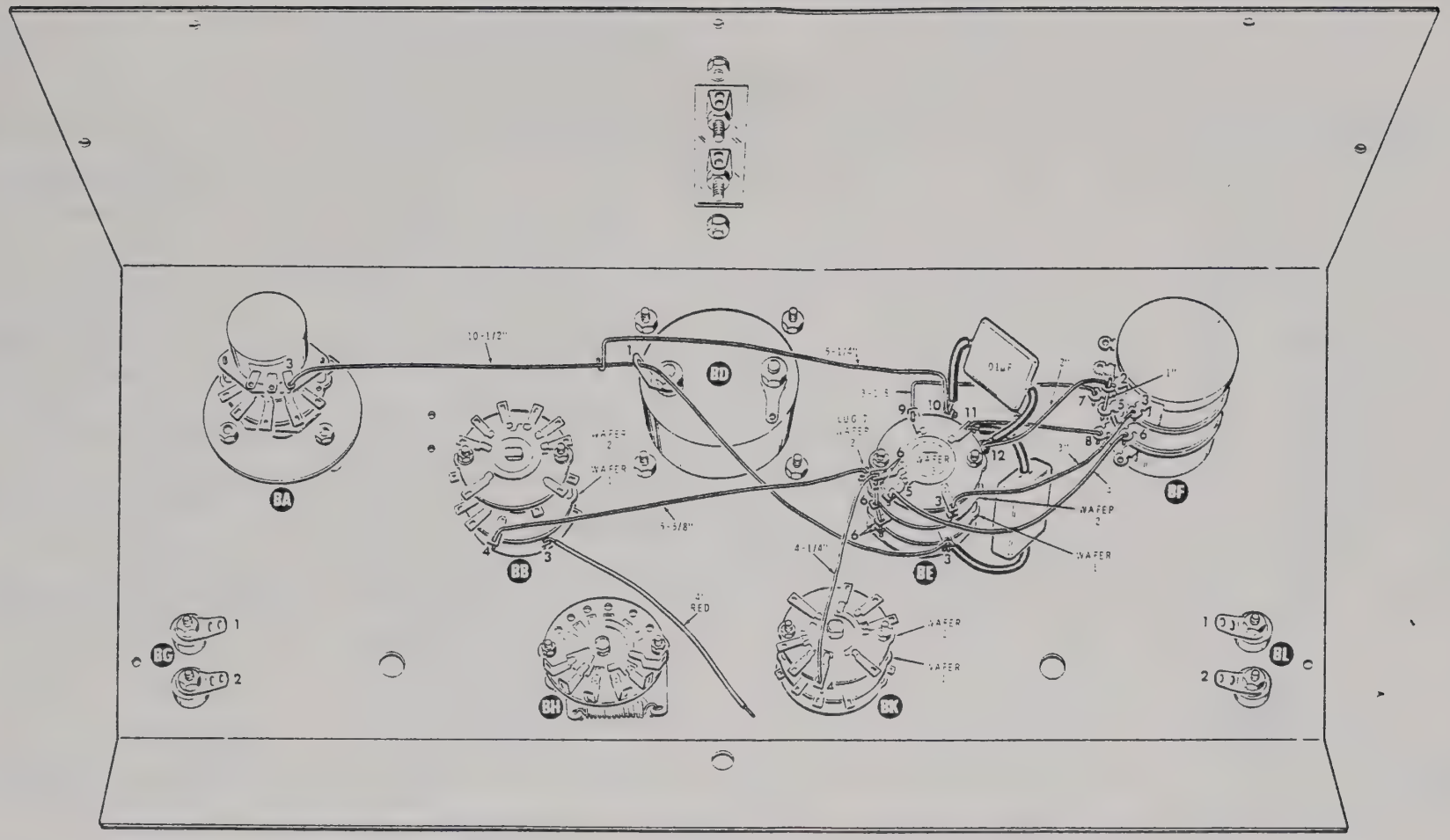
MOUNTING PANEL TO CHASSIS

Refer to Pictorial 9 for the following steps.

( ) Remove the nuts that secure the controls to the chassis at AE and AN.

( ) Position the free ends of the wires coming from switches BB and BK on the front panel out of the way between switches BH and BK.

( ) Place the two holes in the front panel over the shafts of the controls in the front of the chassis. Then secure the pane. to the chassis with two control flat washers and the previously removed control nuts. CAUTION: Be sure none of the wires are pinched between the chassis and front panel.


10-1/2"
5-1/4"
.01mF
WAFER
WAFER
5-5/8"
4-1/4"
RED
WAFER
WAFER
WAFER
WAFER
BA
BB
BD
BE
BF
BG
BH
BK
BL

PICTORIAL 8

FINAL WIRING

Refer to Pictorial 10 (fold-out from Page 23) for the following steps.

Connect the free ends of the wires coming from switch BB as follows:

( ) Black to lug 2 of terminal strip AL (S-2).

( ) Red to lug 2 of terminal strip AK (S-2).

( ) Yellow to lug 1 of terminal strip AK (S-2).

White to lug 4 of terminal strip AL (S-2).

( ) Connect the white wire coming from switch BK to lug 3 of terminal strip AL (S-4).

( ) Connect the black wire coming from switch BK to binding post BL2 (S-1).

( ) Connect the blue lead coming from the bridge transformer to lug 4 on wafer 1 of switch BK (S-1).

In the following steps, you will connect heavy bare wires from switch BK to the two terminal strips (X and Y) on the bridge transformer on the top of the chassis.

( ) Make a 1/8" bend at one end of a 3" bare wire.

( ) Insert the straight end of the 3" bare wire through lug X (NS) on the bridge transformer and on to lug 2 on wafer 2 of switch BK (S-1).

( ) Now solder the bare wire to lug X of the bridge transformer (S-1).

( ) Make a 1/8" bend at one end of a 3-1/4" bare wire.

( ) Insert the straight end of the 3-1/4" bare wire through lug Y (NS) on the bridge transformer and on to lug 8 on wafer 2 of switch BK (S-1).

( ) Now solder the bare wire to lug Y of the bridge transformer (S-1).

( ) Make a small hook at one end of a 3-1/2" bare wire.

( ) From the top of the chassis, insert the straight end of the bare wire down through the solder lug at AK (NS). At the same time, connect the hooked end of the wire around the bare wire through lug 1 of meter BD (S-1).

( ) Cut both leads of a .02 µF Mylar capacitor to 3/4". Connect one lead to lug 11 on wafer 2 of switch BK (S-2). Connect the other lead to the solder lug at AJ (NS).

( ) Connect a 2" white wire from lug 12 on wafer 2 of switch BK (S-2) to lug 1 of terminal strip AJ (S-3).

( ) Connect a 3-1/4" white wire from lug 1 on wafer 1 of switch BK (S-1) to the solder lug at AJ (S-3).

( ) Connect a 3-1/2" white wire from lug 2 of socket V2 (S-2) to lug 3 on wafer 1 of switch BK (S-1).

( ) Remove 1/4" of insulation from one end and 3/4" of insulation from the other end of a 7-3/4" white wire.

( ) Insert the 3/4" bare end through lug 5 on wafer 1 of switch BK (S-2) to lug 5 on wafer 2 of switch BK (S-1).

( ) Connect the other end of the wire to binding post BL1 (S-1).

( ) Connect a 7" white wire from lug 3 of switch BH (S-1) to binding post BG1 (S-1).

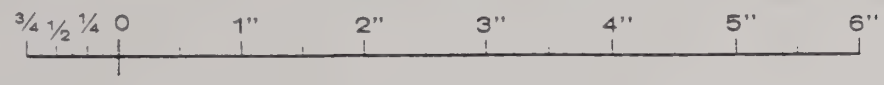
( ) Connect a 2-3/4" white wire from lug 6 of switch BH (S-1) to lug 1 of terminal strip AP (S-1).

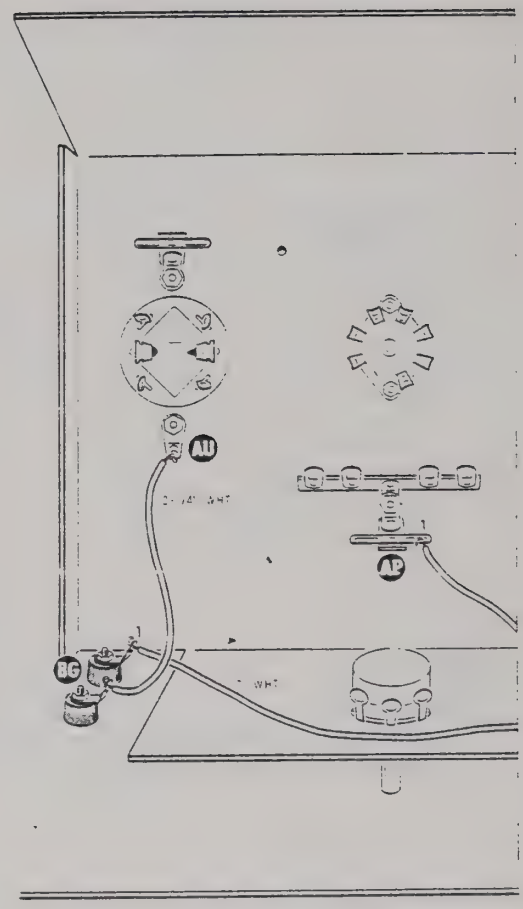
( ) Connect a 2.2 Ω, 2-watt (red-red-gold) resistor from lug 4 of switch BH (S-1) to the solder lug at AK (S-3). NOTE: Now cut off the excess length of heavy bare wire protruding from the solder lug.

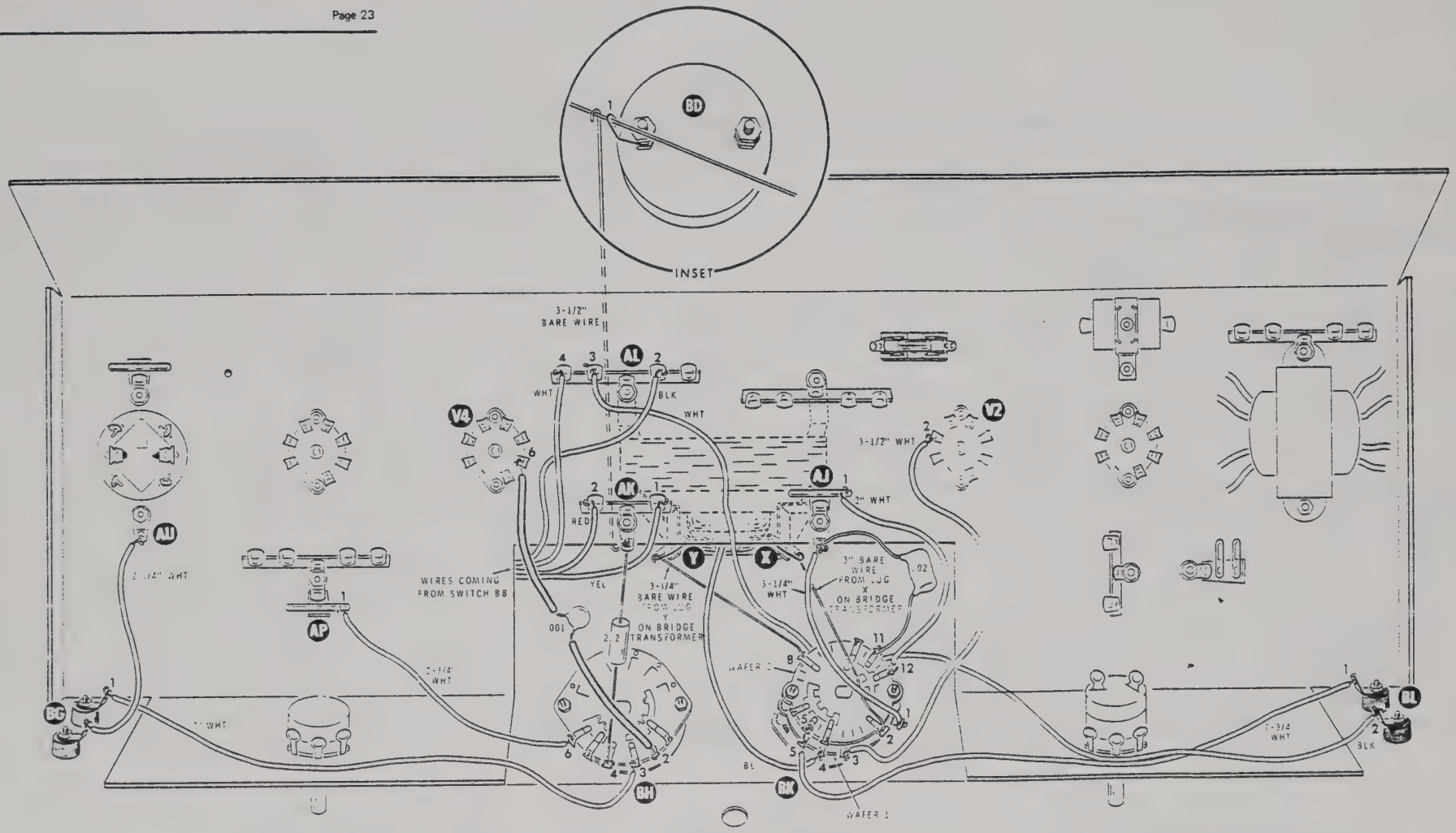
( ) Place 1-1/4" lengths of sleeving on the leads of a .001 µF disc capacitor.

( ) Connect this capacitor from lug 2 of switch BH (S-1) to lug 6 of socket V4 (S-2).

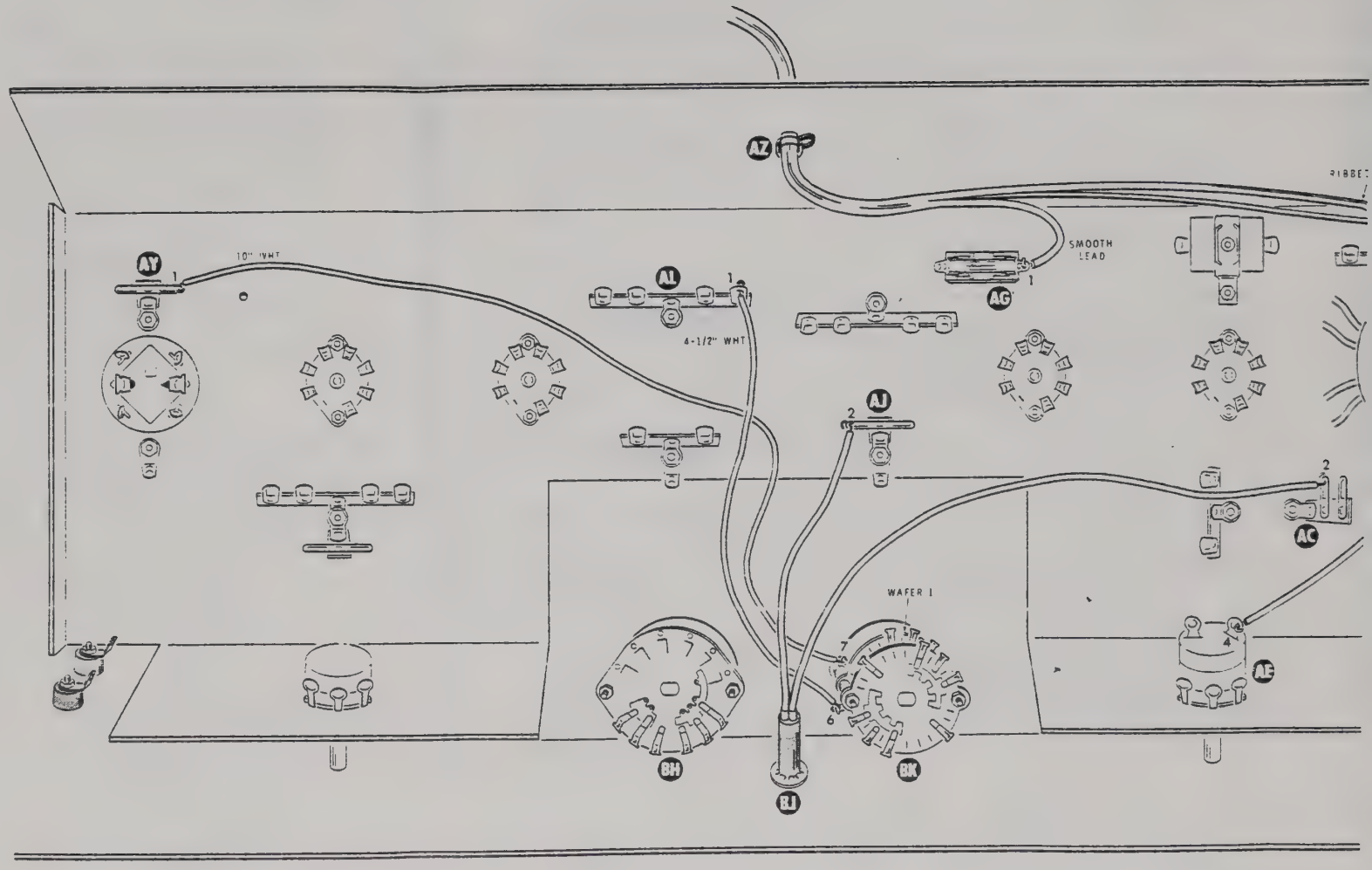
( ) Connect a 2-1/4" white wire from solder lug AU (S-3) to binding post BG2 (S-1).



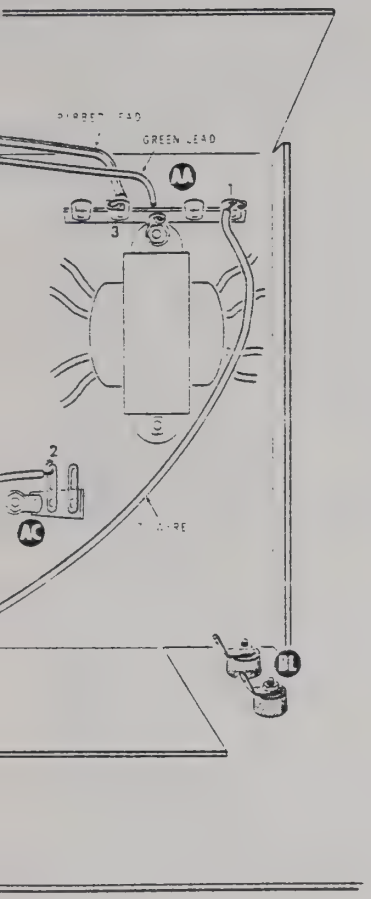




PICTORIAL 10



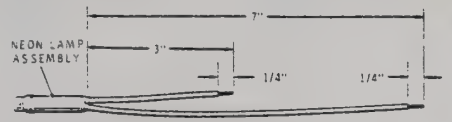
PICTORIAL 11



Refer to Pictorial 11 (fold-out from Page 24) for the following steps.

( ) Connect a 10" white wire from lug 7 on wafer 1 of switch BK (S-1) to lug 1 of terminal strip AY (S-2).

( ) Connect a 4-1/2" white wire from lug 6 on wafer 1 of switch BK (S-1) to lug 1 of terminal strip AL (S-3).

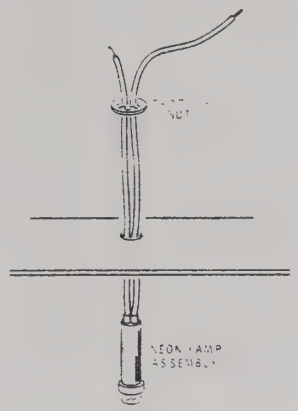


1. CUT THE LEADS TO THE INDICATED LENGTHS.
2. REMOVE 1/4" OF INSULATION FROM THE ENDS OF BOTH LEADS.

NOTE: SAVE THE LONGER CUTOFF LEAD LENGTH.

Detail 11A

( ) Refer to Detail 11A and cut the leads of the neon lamp assembly to the indicated lengths. NOTE: Save the longer of the cutoff lead lengths.

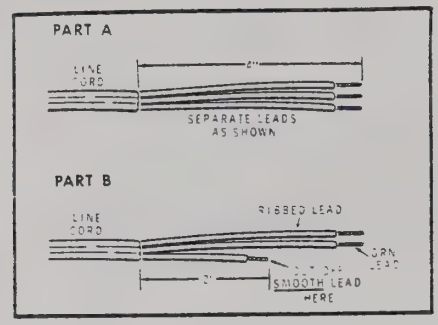


Detail 11B

( ) Refer to Detail 11B and install the lamp assembly in the front panel at BJ. Press the push-on nut firmly against the inside of the front panel.

( ) Connect the shorter lead of the lamp assembly to lug 2 of terminal strip AJ (S-4). Connect the other lead to lug 2 of terminal strip AC (S-3).

( ) Refer to Detail 11C and separate the line cord leads as shown. NOTE: If the ends do not have solder on them, twist the strands together and melt a small amount of solder on each end to keep the strands together.



Detail 11C

Insert the prepared end of the line cord through hole AZ in the rear of the chassis.

NOTES:

1. In the following steps, wrap the ends of the leads around the lug to make a mechanically secure connection before soldering.
2. The edge of one outer lead of the line cord is smooth while the edge of the other outer lead is ribbed for identification purposes. The third lead is green. Be sure you connect the line cord leads as directed in the following steps.

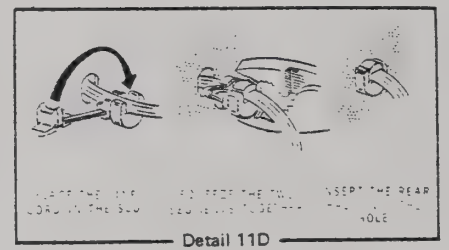
( ) Smooth lead to lug 1 of fuse block AG (S-1).

( ) Ribbed lead to lug 3 of terminal strip AA (S-3).

( ) Green lead to the eyelet of terminal strip AA (S-1).

( ) Use the longer wire previously cut off of the neon lamp assembly and prepare a 7-1/2" length of this wire.

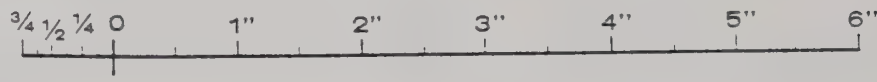
( ) Connect one end of the wire to lug 1 of terminal strip AA (S-3). Connect the other end to lug 4 of switch AE (S-1).

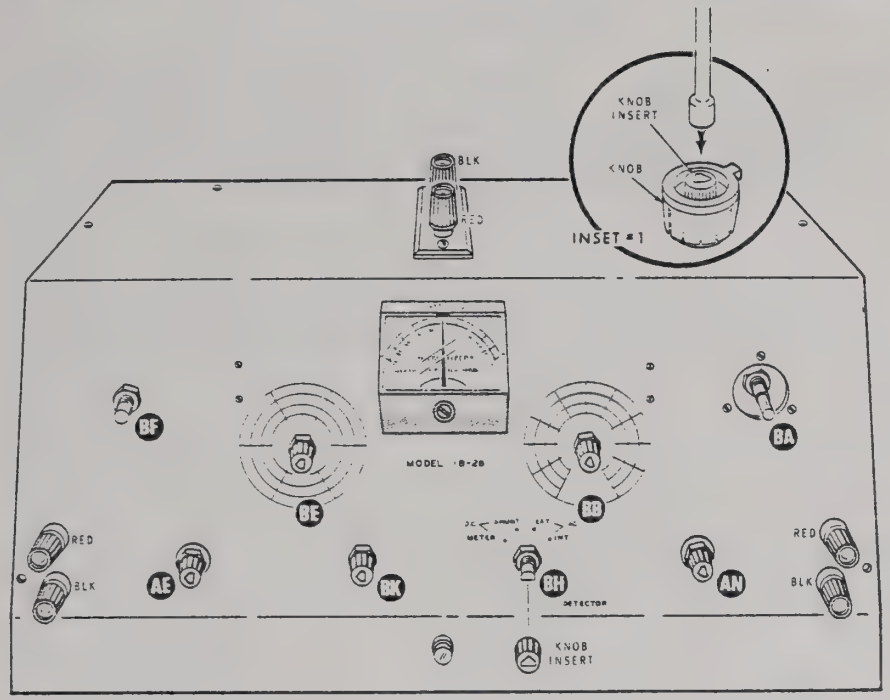


Detail 11D

( ) Refer to Detail 11D and using the appropriate strain relief, secure the line cord in hole AZ in the rear of the chassis.

This completes the wiring of your Impedance Bridge. Carefully inspect the unit to be sure all of the connections are properly soldered. Also, check to be sure the bare wires do not touch each other, the chassis, or any adjacent metal object. If any bare wire touches another bare wire or metal object, carefully move it until it does not touch. The bare wires should clear other objects by approximately 1/4".





PICTORIAL 12

KNOB, DIAL, AND TUBE INSTALLATION

Knobs

Refer to Pictorial 12 and to Figure 1 (fold-out from Page 33) for the following steps.

( ) Press knob inserts on the shafts of controls BE, BB, AE, BK, BH, and AN. Turn the shaft of control BH (Detector Switch) fully clockwise. Turn the remaining five control shafts fully counterclockwise.

( ) Position a small knob over the insert on control BH so its pointer is in line with the black dot at INT on the panel. Then press the knob part way onto the insert.

( ) With the knob still part way on the insert, remove the insert from the shaft. Refer to inset drawing #1 on the Pictorial and with a suitable tool drive the insert as far as it will go into the knob. Then install the knob on the shaft.

CAUTION: After an insert has been pressed into a knob, that knob must be installed on the control shaft at the specified location. The knobs are not functionally interchangeable.

( ) In a similar manner (and one at a time) install pointer knobs on the control shafts at the remaining five locations. The proper position of each knob pointer is shown in Figure 1.

Dials

( ) Turn the shaft of control BF (D-Q dial) fully counterclockwise and place the D-Q dial on the shaft. Do not tighten the dial setscrew at this time.

( ) Refer to Detail 12A and mount the dial pointer for the D-Q dial with two #6 x 3/8" sheet metal screws at the location shown. NOTE: Do not allow your screwdriver to slip and scratch the panel.

( ) Turn the D-Q dial counterclockwise until the long line just above the Q/D-Q marking near the right end of the dial scale is in line with the mark on the D-Q dial pointer. Then tighten the dial setscrew just enough so the shaft of the control will turn when the dial is turned.

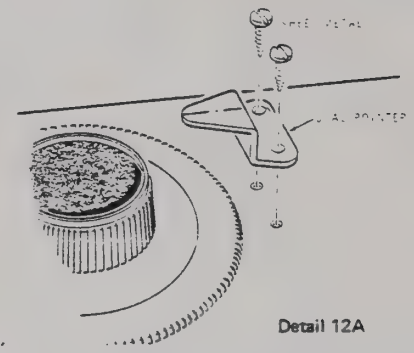
NOTE: Use a pair of pliers when you perform the next step. Be careful so you do not damage the shafts of the control.

( ) Turn the outer (switch) shaft of control BA fully counterclockwise. Then turn it clockwise until it detents (clicks) five times. Turn the inner shaft of the control fully clockwise.

( ) Place the C-R-L switch dial on the outer shaft and the C-R-L control dial on the inner shaft of control BA. The setscrews will be tightened later.

( ) Refer to Detail 12A and mount the pointer for the C-R-L dials with two #6 x 3/8" sheet metal screws at the location shown.

( ) Turn the C-R-L switch dial (outer ring) until the number 5 is directly in line with the mark on the C-R-L dial pointer. Then securely tighten the setscrew in the dial. NOTE: The setscrew is accessible from behind the front panel.



Detail 12A

( ) Turn the C-R-L control (inner) dial clockwise until the 1.2 mark on the dial scale is at the CRL mark on the switch dial.

CAUTION: Do not overtighten the setscrew when you perform the next step.

( ) Tighten the setscrew in the C-R-L (inner) dial just enough to cause the control shaft to turn when the dial is turned.

( ) Refer to Pictorial 12 and install binding posts caps of the proper color on the six binding posts.

Tubes

WARNING: A MINIATURE TUBE CAN EASILY BE DAMAGED WHEN IT IS INSTALLED IN ITS SOCKET. LINE UP THE TUBE PINS WITH THE SOCKET HOLES. THEN FIRMLY BUT CAREFULLY PRESS DOWN ON THE TUBE AND WORK THE PINS ALL THE WAY INTO THE SOCKET. THE WARRANTY DOES NOT APPLY TO A TUBE THAT IS BROKEN DURING INSTALLATION.

Refer to Figure 2 and install the tubes as follows:

( ) 1U4 tubes at V1 and V4.

( ) 1L4 tubes at V2 and V3.

( ) Be sure the tube pins do not touch a resistor or capacitor lead. This could burn out a tube

TEST AND ADJUSTMENT

CAUTION: Both the case and circuit ground of the Impedance Bridge are connected to the power line ground through the green lead of the line cord. When the Impedance Bridge is used in conjunction with a device such as an oscilloscope or other external instrument, the black EXT DET binding post (BL2) on the Impedance Bridge should always be connected to the chassis (ground) of the external instrument.

Refer to Figure 1 (fold-out from Page 33) for the following step.

( ) Check the position of the meter pointer. If necessary, use a small screwdriver and slowly turn the adjustment screw in the front of the meter and adjust the pointer to zero at the center of the meter scale.

INITIAL TEST

Preset the controls as follows:

	Dial or Knob	Set To:
( )	FUNCTION switch	R
( )	RANGE switch	1h
( )	GEN LEVEL control	Fully counterclockwise
( )	GENERATOR switch	AC EXT.
( )	DETECTOR switch	AC EXT.
( )	SET AC ZERO control	Fully counterclockwise

NOTE: If you do not obtain the results specified in the following steps, refer to the "In Case of Difficulty" section and the "Troubleshooting Charts" in this Manual before you proceed with the adjustments.

( ) Insert the line cord plug into a suitable 50/60 Hz power outlet and turn the GEN LEVEL control just until the switch clicks on. The panel lamp should light.

( ) Turn the GENERATOR switch; then the DETECTOR switch to their AC INT positions. The meter pointer should move to left full scale.

( ) Adjustment of either the GEN LEVEL or the SET AC ZERO controls should now cause the meter pointer to move across the scale to the right.

Turn off the Impedance Bridge. This completes the "Initial Tests."

ADJUSTMENTS

The oscillator circuit is designed to operate between 800 and 1200 Hz. A trimmer capacitor is provided so the oscillator frequency can be set to 1000 Hz. Use either an audio generator and an oscilloscope, or an audio generator and headphones. Both methods are described below. Use only one of the methods.

Generator and Oscilloscope Method

Set the Impedance Bridge controls and switches as directed in the following steps. NOTE: Disregard the D-Q and C-R-L dial positions.

( ) FUNCTION switch to R.

( ) RANGE switch to 1h.

( ) GENERATOR switch to AC INT.

( ) DETECTOR switch to AC EXT.

( ) SET AC ZERO control fully counterclockwise.

( ) Set the audio generator to 1000 Hz and connect its output cable to one pair of deflection plates of the oscilloscope.

( ) Connect the terminals on the top of the Impedance Bridge to the other pair of oscilloscope deflection plates.

( ) Turn on the Impedance Bridge. Rotate the GEN LEVEL control to its fully clockwise position.

NOTE: Refer to Figure 2 (fold-out from Page 33) for the location of trimmer capacitor C2.

( ) Use a small screwdriver and, from the top of the chassis, turn the screw in trimmer capacitor C2 clockwise as far as it will go. Then turn the screw counterclockwise 3/4 of a turn.

( ) Adjust trimmer capacitor C2 until a circle or ellipse appears on the oscilloscope screen.

The frequency of the oscillator in the Impedance Bridge is now equal to the frequency of the audio generator. Turn the GEN LEVEL control fully counterclockwise to turn off the Impedance Bridge. Then proceed to "C-R-L Dial Adjustment" on Page 29.

Generator and Headphone Method

Set the Impedance Bridge controls and switches as directed in the following steps. NOTE: Disregard the D-Q and C-R-L dial positions.

( ) FUNCTION switch to R.

( ) RANGE switch to 1h.

( ) GENERATOR switch to AC INT.

( ) DETECTOR switch to AC EXT.

( ) SET AC ZERO control fully counterclockwise.

( ) Set the audio generator to 1000 Hz. Then connect its output cable to the terminals on the top of the Impedance Bridge.

( ) Connect the headphone leads to the EXT DET binding posts on the front panel.

( ) Turn on the Impedance Bridge. Rotate the GEN LEVEL control to its fully clockwise position.

( ) Use a small screwdriver and, from the top of the chassis, turn the screw in trimmer capacitor C2 clockwise as far as it will go. Then turn the screw counterclockwise 3/4 of a turn. You should now hear the 1000 Hz signal from the audio generator and a slightly higher tone signal from the impedance bridge. These signals combine to produce a throbbing tone in the headphones.

NOTE: As the adjustment of the trimmer capacitor approaches the null point in the following step, the beat of the throbbing tone you hear will become slower and slower and finally disappear. This null point is quite critical. Therefore, you may have to perform the adjustment several times. When the capacitor is properly adjusted only a single steady 1000 Hz tone will be heard.

( ) Very slowly turn the trimmer capacitor screw clockwise until a null point is reached where only a single steady tone is heard. CAUTION: If you "overshoot" the null point, turn the screw counterclockwise; then turn it clockwise again to obtain the proper null adjustment.

The frequency of the oscillator in the Impedance Bridge is now equal to the frequency of the audio generator. Turn the GEN LEVEL control fully counterclockwise to turn off the Impedance Bridge. Then proceed to "C-R-L Dial Adjustment."

C-R-L Dial Adjustment

Refer to Figure 1 (fold-out from Page 33) for the following steps.

Set the controls and switches as follows:

( ) FUNCTION switch to R.

( ) GENERATOR switch to DC INT.

( ) DETECTOR switch to DC SHUNT.

( ) RANGE switch to 100 Ω on the "R" scale.

( ) C-R-L switch dial to 5.

( ) Insert banana-plugs-with-clips in the red and black binding posts on the top of the impedance bridge. Then locate the previously set aside 550 Ω, precision resistor and connect it between the clips in the binding posts.

( ) Turn the C-R-L control dial fully counterclockwise and turn on the Impedance Bridge with the GEN LEVEL control. The meter pointer should remain at or slightly to the left of 0 at the center of the meter scale.

NOTE: The DETECTOR switch is "spring-loaded" in its METER position. This means that you must turn and hold the knob counterclockwise to obtain a reading in the METER position. The switch will return to the DC SHUNT position when the knob is released.

( ) Turn the DETECTOR switch to the DC METER position and note that the meter pointer will move full scale to the left. The pointer will return to or near zero when the knob is released.

( ) Rapidly turn the DETECTOR switch knob back and forth between the DC METER and DC SHUNT positions. At the same time, turn the C-R-L control dial clockwise until there is no change in meter reading with switch rotation.

( ) Hold the C-R-L control dial so it cannot move and loosen the dial setscrew. Now carefully turn the dial until .5 on its scale is in line with the mark on the C-R-L dial pointer. The C-R-L dials should now read 5.5.

( ) Carefully tighten the dial setscrew and again check to be sure there is no change in meter reading when the DETECTOR switch knob is rotated back and forth between the DC METER and DC SHUNT positions. Repeat this adjustment until no change in meter reading occurs.

( ) Turn the GENERATOR and DETECTOR switches to their AC EXT positions and remove the 550 Ω, precision resistor from the clips in the binding posts.

( ) Turn the GEN LEVEL control fully counterclockwise to turn off the Impedance Bridge.

The C-R-L dials are now set properly and ready for use.

CALIBRATING D-Q DIAL

NOTE: Perform the following steps only if you desire D-Q dial accuracy greater than that obtained by previously setting the mark on the Q/D-Q dial scale to the mark on the D-Q dial pointer.

Refer to Figure 3 for the following steps.

( ) Unplug the line cord from the power outlet.

( ) Unsolder the control end of the bare wire connected between lug 12 on wafer 3 of switch BE and lug 2 of control BF. Then carefully bend the bare wire away from the control lug.

( ) Temporarily connect a jumper wire or clip lead from lug 2 of control BF to terminal 2 (red binding post) on the top of the impedance bridge.

( ) Connect another jumper wire or clip lead from lug 3 of control BF to binding post 1 (black) on the top of the impedance bridge.

Set the dials and control knobs as follows:

( ) D-Q dial to 3 of the D-Q scale.

( ) C-R-L switch dial to 4.

( ) C-R-L control dial to .8 on the scale.

( ) FUNCTION switch to R.

( ) RANGE switch to 1 kΩ.

( ) GENERATOR switch to DC INT.

( ) DETECTOR switch to DC SHUNT.

( ) Turn the GEN LEVEL control clockwise to turn on the Impedance Bridge.

( ) Turn the DETECTOR switch knob to the DC METER position. The meter should read between 0 and 40 microamperes. NOTE: This reading may be to the right or to the left of the meter's zero center.

( ) Hold the DETECTOR switch knob in the DC METER position and at the same time adjust the D-Q control knob until the bridge is balanced (meter pointer to zero at center of scale). This should occur near the 20 mark on the Q scale of the D-Q dial.

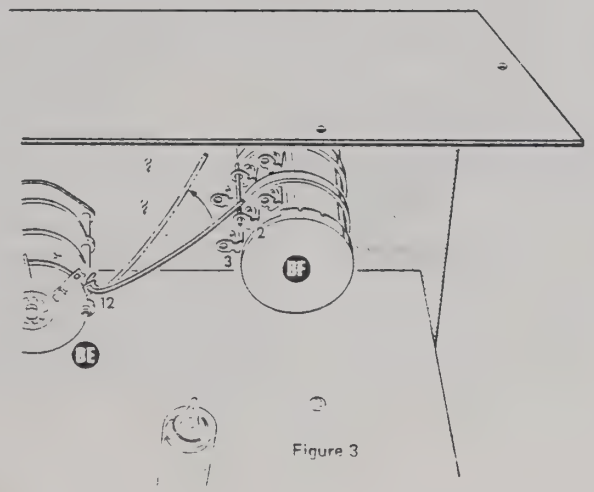


Figure 3

NOTE: The following adjustment is quite critical, therefore the procedure may have to be performed several times to obtain the proper null.

( ) Rapidly turn the DETECTOR switch knob back and forth between the DC METER and DC SHUNT positions. At the same time, adjust the D-Q dial until there is no change in meter reading with switch rotation.

( ) Hold the dial so it cannot move and loosen the setscrew. Now carefully turn the dial until 3 of the D-Q scale is in line with the mark on the dial pointer.

( ) Carefully tighten the dial setscrew and again check to be sure there is no change in meter reading when the DETECTOR switch knob is rotated back and forth between the DC METER and DC SHUNT positions. Repeat this procedure until no change in meter reading occurs with the D-Q dial set at 3 on the D-Q scale.

Check the D-Q dial calibration by performing the following steps.

( ) Set the D-Q dial to 8 on the D-Q scale.

( ) Turn the Range switch to the 10 kΩ position.

( ) Turn the C-R-L switch dial to 1.

( ) Hold the DETECTOR switch in the DC METER position and at the same time adjust the C-R-L control dial until the meter reads zero.

( ) The C-R-L dials should read 1.28 ± one scale division (.01) on the C-R-L control dial scale.

( ) Tighten the setscrew in the D-Q dial and unplug the power cord.

( ) Remove both of the jumper wires or clip leads connected between control BF and the binding posts on the top of the bridge.

( ) Solder the previously disconnected bare wire to lug 2 of control BF (S-1).

This completes the adjustments of your Impedance Bridge. Proceed with the "Final Assembly" steps.

FINAL ASSEMBLY

Refer to Pictorial 13 (fold-out from Page 33) for the following steps.

NOTE: The blue and white identification label, that will be installed in the next step, shows the model number and production series number of your kit. Refer to these numbers in any communications you have with the Heath Company about this kit. This assures you that you will receive the most up-to-date information in return.

( ) Carefully peel the backing paper from the blue and white identification label and position the label on the chassis as shown. Place the backing paper over the label; then firmly press the label onto the chassis.

( ) Remove the backing paper from the fuse label. Then press the label on the chassis as shown in the Pictorial. Mark the fuse type and rating on the label.

( ) Refer to the inset drawing on the Pictorial. Then, from the outside, install rubber feet in the four holes in the cabinet bottom.

( ) Insert the line cord plug through the cutout in the back of the cabinet. Then carefully mount the chassis and panel assembly in the cabinet.

( ) Be sure the line cord is not pinched between the cabinet and chassis. Then secure the cabinet to the back of the chassis with two #6 x 3/8" sheet metal screws.

( ) Line up the holes in the cabinet with the matching holes in the panel and secure the panel to the cabinet with #6 x 3/8" sheet metal screws at the seven indicated locations. CAUTION: Be careful so the screwdriver does not slip and scratch the panel.

This completes the assembly of your Impedance Bridge.

OPERATION

Make all Impedance Bridge measurements with the leads or connections of the unknown disconnected from all associated circuitry.

CAUTION: Both the case and circuit ground of the Impedance Bridge are connected to the power line ground through the green lead of the line cord. When the unknown is mounted in an external device, always connect the black EXT DET binding post on the Bridge to the chassis of the external device.

Low resistance measurements are subject to error due to the internal resistance of the bridge and the resistance of the contacts and leads. The internal resistance of the bridge can be measured by shorting the unknown binding posts with a piece of heavy wire and balancing the bridge in the normal manner. The internal resistance will probably be in the order 0.02 Ω. Lead resistance can be minimized by connecting the resistance to be measured directly between the binding posts. Cleaning the leads will also help to minimize errors due to lead resistance. When measuring low values of resistance, the internal resistance of the bridge should be determined and then subtracted from the measured value.

DC RESISTANCE MEASUREMENTS

Refer to Figure 1 (fold-out from Page 33) for the following steps.

1. Check the position of the meter pointer. If necessary, adjust the meter screw until the pointer indicates exactly zero.
2. Connect the unknown resistance between the binding posts on the top of the bridge.
3. Set the FUNCTION switch to R.
4. Set the GENERATOR switch to DC INT.
5. Set the DETECTOR switch to DC SHUNT.
6. Set both C-R-L dials to 0.
7. Plug in the line cord and turn on the Impedance Bridge.
8. Turn the RANGE switch to the position that results in minimum deflection of the meter pointer. NOTE: Choose a switch position that will give a reading to the left of the zero mark at the center of the scale.
9. Turn the C-R-L switch (outer) dial until approximate balance is obtained. Then adjust the C-R-L control (inner) dial for further balance.
10. To obtain final balance, rapidly turn the DETECTOR switch knob back and forth between the DC SHUNT and DC METER positions and, at the same time, adjust the C-R-L control dial until there is no change in the meter reading with switch rotation.
11. Multiply the readings of the C-R-L dials by the reading of the RANGE switch to determine the value of the unknown resistance. For resistance measurements below 1 Ω, it is recommended that an external galvanometer with a greater sensitivity be used.

External batteries as specified in the following chart may be used to obtain greater indicating accuracy of DC resistance measurements. CAUTION: WHEN EXTERNAL BATTERIES ARE USED, THE C-R-L SWITCH DIAL MUST NOT BE TURNED BELOW "1".

RANGE switch position:	Maximum of:	In series with:
0.1 Ω, 1.0 Ω, 10 Ω, 100 Ω	67-1/2 volts	Not less than 1500 Ω
1 kΩ	135 volts	Not less than 4000 Ω
10 kΩ, 100 kΩ, 1 MEG	202-1/2 volts	Not less than 6500 Ω

INDUCTANCE MEASUREMENTS AT 1000 Hz

NOTE: When the GENERATOR switch is in the AC INT position, inductance measurements are made using 1000 Hz, which is the frequency of the generator in the bridge. Inductance measurements may be made at other frequencies by connecting an external generator to the EXT GEN binding posts and placing the GENERATOR switch in the AC EXT position.

1. Connect the unknown inductor to the binding posts on the top of the bridge.
2. Set the GENERATOR switch to AC EXT.
3. Set the DETECTOR switch to AC INT.
4. Set the FUNCTION switch to L/DQ.
5. Set the D-Q dial to 5 on the D-Q scale.
6. Set the C-R-L switch dial to 1 and the C-R-L control dial to .5.
7. Turn the GEN LEVEL control clockwise just enough to turn the bridge on.

NOTE: In the next step, the SET AC ZERO control will be adjusted to set the meter pointer to a reading of 100 μA. This will be the point to which the bridge will be balanced in the remaining steps.

8. Adjust the SET AC ZERO control so the meter pointer indicates 100 μA at the left end of the meter scale. NOTE: DO NOT CHANGE the setting of this control throughout the following adjustments.

NOTE: Disregard the next step if an external generator is being used.

9. Set the GENERATOR switch to AC INT.
10. Adjust the GEN LEVEL control until the meter reads approximately half-scale.
11. Turn the RANGE switch to the position that will produce the greatest deflection of the meter pointer toward the left end of the scale.
12. Simultaneously adjust the D-Q dial and the C-R-L dials until the meter pointer moves toward the 100 μA balance point at the left end of the scale. Adjust the GEN LEVEL control clockwise as balance is approached so that at final balance the control will be turned fully clockwise. NOTE: If when balance is approached the D-Q dial setting is above 10 on the D-Q scale, set the FUNCTION switch to L/Q and perform the adjustments in steps 8 through 12.
13. Multiply the reading of the C-R-L dials by the L-scale reading of the RANGE switch to determine the value of the inductance (L). Read the value of Q directly from the Q or D-Q scales on the D-Q dial.

CAPACITANCE MEASUREMENTS AT 1000 HZ

NOTE: When the GENERATOR switch is in the AC INT position, capacitance measurements are made using 1000 Hz, which is the frequency of the bridge generator. Capacitance measurements may be made at other frequencies by connecting an external generator to the EXT GEN binding posts and placing the GENERATOR switch in the AC EXT position. In this case, disregard step 2 as you perform the following measurement procedure.

1. Connect the unknown capacitance to the binding posts on top of the bridge.
2. Set the GENERATOR switch to AC INT.
3. Set the DETECTOR switch to AC INT.
4. Set the FUNCTION switch to C/DQ.
5. Set the D-Q dial to zero on the DQ scale.
6. Set the C-R-L switch dial to 1 and the C-R-L control dial to .5.
7. Turn the GEN LEVEL control clockwise just enough to turn the bridge on.

NOTE: In the next step, you will adjust the SET AC ZERO control to set the meter pointer to a reading of 100 μA. This will be the point to which the bridge will be balanced.

8. Adjust the SET AC ZERO control so the meter pointer indicates 100 μA at the left end of the meter scale. NOTE: DO NOT change the setting of this control throughout the following steps.
9. Adjust the GEN LEVEL control until the meter reads approximately half-scale.
10. Turn the RANGE switch to the position that will produce the greatest deflection of the meter pointer toward the left end of the scale.
11. Simultaneously adjust the D-Q dial and the C-R-L dials until the meter pointer moves toward the 100 μA balance point at the left end of the scale. Also adjust the GEN LEVEL control clockwise as balance is approached so that at final balance, the control will be turned fully clockwise.

NOTE: If the D-Q dial setting will be below 1 on the D-Q scale when balance is obtained, set the FUNCTION switch to C/D and again perform steps 8 through 12.

12. Multiply the reading of the C-R-L dials by the C-scale reading of the RANGE switch to determine the value of capacitance (C).

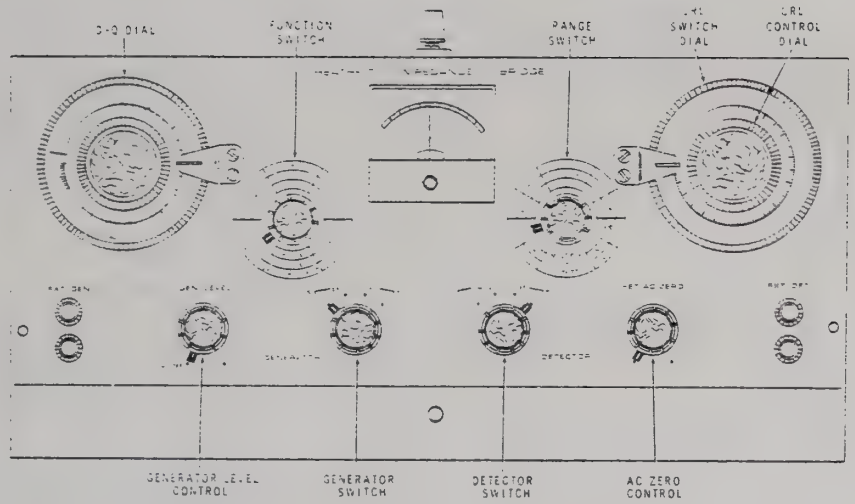


Figure 1

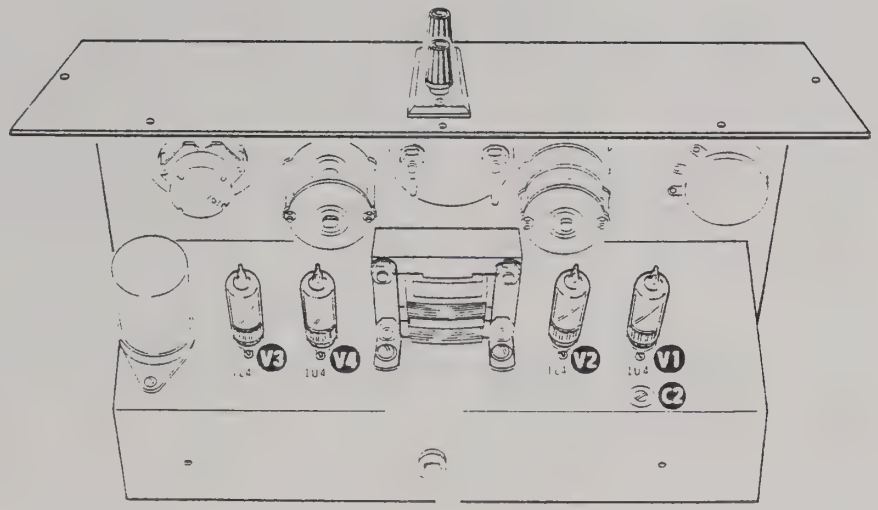
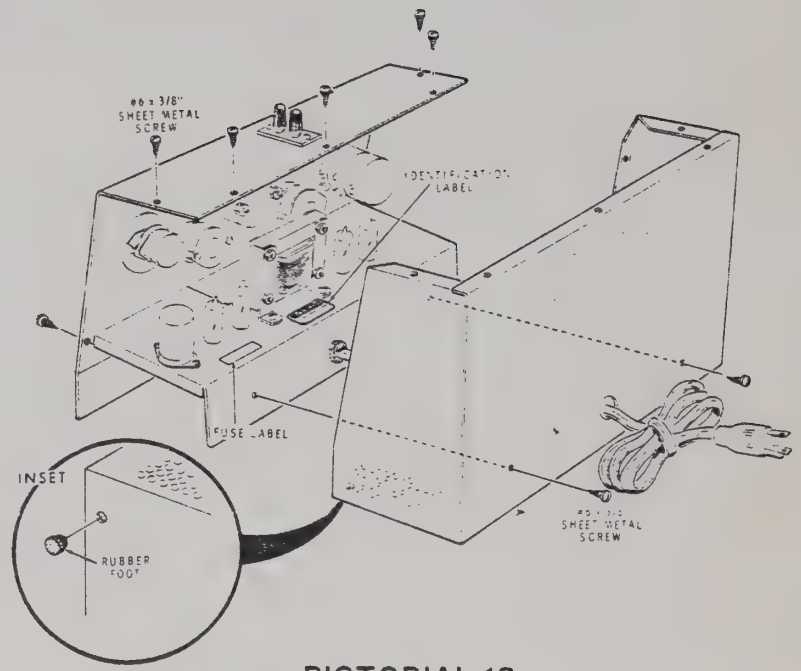


Figure 2



PICTORIAL 13

Dissipation factor D and storage factor Q are both frequency dependent. For a frequency of 1 kHz (the internal generator frequency), the dissipation factor and storage factor are direct reading on both the Q and D-Q dial scales. For a frequency other than 1 kHz, a correction factor must be applied to the dial reading obtained. Using an external generator at a frequency other than 1 kHz, the corrected dissipation factor D will be the value of the dial reading obtained at balance, multiplied by the frequency in kHz.

Under the same frequency condition and using the D-Q scale, the corrected storage factor Q will be the value of the dial reading at balance multiplied by the frequency in kHz. Using the Q scale, the corrected storage factor Q will be the value of the dial reading at balance divided by the frequency in kHz.

IN CASE OF DIFFICULTY

The following paragraphs deal with difficulties that might occur during the "Tests and Adjustments" and which must be corrected before the kit can be placed in normal operation. This type of difficulty is usually due to an assembly error or to an improperly soldered connection. The following checks should help you locate an error of this type if one has been made.

1. Make a careful visual check of the complete unit for any obvious error that may have been made, such as improperly soldered connections, wiring errors, bare wires touching each other, etc. Look for bits of solder, pieces of wire, or other foreign matter lodged in the wiring or components that could cause trouble. Carefully check all points where several connections are made to make sure all wires are properly soldered.

2. Make sure each wire or lead is connected to the proper place. It is quite helpful to have another person check your work. Someone familiar with the unit will often notice an error that you have overlooked.

3. Carefully check all solder connections. About 90% of the kits that are returned to Heath Company for service operate improperly due to poor solder connections. Reheat questionable connections and, if necessary, apply a little more solder to make sure connections are soldered as described in the "Soldering" section of the "Kit Builders Guide."

4. Check the values of the parts. Be sure the proper parts have been wired into each circuit as shown in the Pictorials. It would be easy, for example, to install a 1000 Ω (brown-black-red) resistor where a 10 kΩ (brown-black-orange) resistor should have been installed.

5. Check the voltages between the lugs of the tube sockets and the chassis. These voltages should be within ±10% of the values listed in the "Voltage Chart" and indicated on the Schematic (fold-out from Page 45).

In an extreme case where you are unable to resolve a difficulty, refer to the "Customer Service" information inside the rear cover of the Manual. Your Warranty is located inside the front cover.

VOLTAGE MEASUREMENTS

Preset the controls and switches as follows before you take the readings listed in the following chart.

Control or Switch:	Set to:
GENERATOR switch	AC INT
DETECTOR switch	AC INT
FUNCTION switch	Full clockwise rotation
RANGE switch	Full clockwise rotation
GEN LEVEL control	Full clockwise rotation

NOTE: Unless otherwise indicated, voltages are positive. Readings were taken with a high input impedance voltmeter, from the point indicated to chassis ground.

Voltage Chart

SOCKET AND TUBE	LUG 1	LUG 2	LUG 3	LUG 4	LUG 5	LUG 6	LUG 7
V1/1U4	0	50 to 55	45 to 50	NC	0	−.35	1.4
V2/1L4	1.4	105	110	NC	1.4	.48	2.5
V3/1L4	1.4	100	110	NC	1.4	−24	2.5
V4/1U4	0	45	36	NC	0	−.5	1.4

SPECIFICATIONS

Circuit	4-arm bridge for measuring all types of impedance. Also includes a 1 kHz generator circuit and a detector circuit.
Detector	Vacuum tube type with meter rectifier. Binding posts provided for connection of external detector.
Generator	Vacuum tube type operating at 1 kHz. Binding posts provided for connection of external generator for measurements at other frequencies.
Measurements	
Resistance	0.1 Ω to 1 MΩ.
Inductance	0.1 mH to 100 H.
Capacitance	100 pF to 100 μF.
Dissipation Factor (D)	0.002 to 1.0.
Storage Factor (Q)	0.1 to 1000.
Accuracy of Bridge Circuit Components	1/2 of 1%.
Accuracy of Measurements	Limited only by interpretation of scales and quality of workmanship during assembly.
Resistance	±3%.
Inductance	±10%.
Capacitance	±3%.
Dissipation Factor (D = W/R)	±20%.
Storage Factor (Q = WL/R)	±20%.
	(Accuracy will fall off at extreme outer limits.)

Meter	Zero center, 100-0-100 μA
Rectifier	1N191 germanium diode.
Tube Complement	
Internal Generator	1U4 (V1) and 1L4 (V2).
Internal Detector	1L4 (V3) and 1U4 (V4).
Power Supply	Power transformer.
	Half-wave, silicon diode.
	Four 1N4002 silicon diodes arranged in a full-wave bridge-rectifier circuit.
Power Requirements	105-125 VAC or 210-250 VAC, 50/60 Hz, 10-watts. Fused with 1/8-A, slow-blow, 3AG type fuse.
Overall Dimensions	9" high x 16-1/2" wide x 6-1/2" deep.
Net Weight	11 lbs.

BRIDGE THEORY OF OPERATION

A bridge is an arrangement of impedances used to measure various electrical properties. When used for direct current measurement of resistance, the bridge generally takes the form of the Wheatstone bridge with four resistance arms, which is the standard method for accurate measurement of resistance.

For measurement of circuit constants at audio frequencies, the alternating-current bridge is the most widely used device. Inductance and capacitance measurements are made conveniently and accurately by this method. The type of alternating current bridge circuit is determined by the measurement to be made. The circuits are all adaptations of the basic Wheatstone bridge circuit.

An important characteristic of a coil or capacitor which can be conveniently measured in an AC bridge is the ratio of resistance to reactance. This ratio is defined as the dissipation factor D. Its reciprocal is defined as the storage factor Q. The defining equations are as follows:

$$D = \frac{1}{Q} = \frac{R}{X} \qquad Q = \frac{1}{D} = \frac{X}{R}$$

where R is the series resistance and X is the reactance of the inductance or capacitance being measured.

The dissipation factor D is directly proportional to the energy dissipated per hertz, while the storage factor Q is directly proportional to the energy stored per hertz. Dissipation factor is most commonly used for capacitors because it varies directly with the loss. Storage factor Q is commonly used for inductors because it is a measurement of the voltage step-up in a tuned circuit.

In its basic form, the bridge consists of four impedance arms: A, B, C, and D; as shown in Figure 4. The ratio of A and B is switch selective so that the variable arm D can serve as a standard for measuring many values of the unknown C. The four impedances are connected in series-parallel to a source of potential, E, applied between the junctions of A/C and B/D. When the voltage drop across arm A is equal to the voltage drop across arm C, no current will flow through the detector and the bridge is in balance. This balance condition may be indicated by the formula.

$$\frac{A}{C} = \frac{B}{D}$$

Two conditions are necessary for balance. Both the magnitudes of the impedances and the phase angles must be equal.

By the proper use of resistances, capacitors, inductors, or resistor-capacitor combinations in series or parallel, the bridge may be used for measuring resistance (R), capacity (C), inductance (L), dissipation factor (D), and storage factor (Q).

Various bridge combinations are selected by setting the Function switch to the appropriate position. The ratio arms (A and B) of the bridge are selected by the Range switch. Balance is obtained by adjusting the D-Q and C-R-L dials.

RESISTANCE MEASUREMENTS

The Wheatstone bridge is still considered to be the fundamental circuit for accurate measurement of DC resistance. A 4-arm bridge, the fourth arm being the unknown as shown in Figure 5, is used for resistance measurements. The basic equation of balance for the Wheatstone bridge is:

$$R_x = \frac{R_D R_A}{R_B}$$

with R_x being the value of the unknown resistance. R_D is indicated by the readings of the C-R-L control dials and the ratio R_A/R_B is indicated by the dial reading of the Range switch. The value of the unknown resistance is the product of the readings of the Range switch and the C-R-L dials when the bridge is balanced.

CAPACITY MEASUREMENTS

A Capacitance-Comparison bridge is used to measure capacity. This bridge circuit uses a precision capacitor (a standard) in series with a variable resistance as shown in Figure 6. Dissipation factor is also measured using this circuit.

INDUCTANCE MEASUREMENTS

The Maxwell bridge circuit (Figure 7) is used to measure inductance when the storage factor (Q) of the unknown inductance is less than 10. In this bridge circuit, the inductance is measured in terms of capacitance.

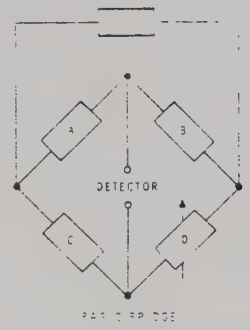


Figure 4

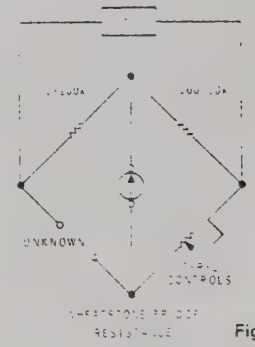


Figure 5

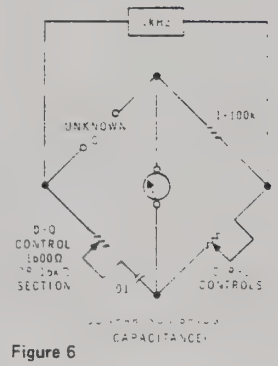


Figure 6

Figure 7

A capacitor has some advantages as a "standard" since practically no external field is produced and the capacitor is quite compact. In this circuit the "standard" capacitor is in parallel with the D-Q control.

The Hay bridge circuit (Figure 8) is used to measure inductances when the storage factor (Q) of the unknown inductance is between 10 and 1000. In this circuit, which is a modification of the Maxwell bridge, the "standard" capacitor is in series with the D-Q control.

Figure 8

D-Q CONTROL DESIGN DATA

The theoretical relationship between specific "D" or "Q" readings, as indicated by the setting of the D-Q dial and the corresponding value of resistance at that control setting, is shown in the following table. The dial's intermediate calibration marks are based on the theoretically linear characteristics of the rear and center sections (D and C) of the D-Q control and the tapered characteristic (two linear elements) in the front section (A) of the control. The overall resistance of each section of the control is held to within 5% of its specified value.

DIAL READING	SECTION A OHMS	DIAL READING	SECTION B OHMS	SECTION C OHMS
Stop	0	Stop	1600	16000
1000	1.7	10	1600	16000
500	3.27	9.0	1440	14400
400	4.1	8.0	1280	12800
300	5.95	7.0	1120	11200
200	8.1	6	960	9600
150	10.8	5	800	8000
100	16.1	4	640	6400
90	17.7	3	480	4800
80	20.1	2	320	3200
70	23.0	1	160	1600
60	26.8	0.8	128	1280
50	32.0	0.6	96	960
45	35.6	0.4	64	640
40	40.3	0.2	32	320
35	46.6	0.1	16	160
30	54.3	0	0	0
25	66.3	Stop	0	0
20	83.0			
18	92.5			
16	103.0			
14	113.0			
12	138.0			
10	165.0			
Stop	185.0			

CIRCUIT DESCRIPTION

Except for the Generator Level and the Set AC Zero controls, the front panel controls and switches function as the arms of the bridge circuitry. The remaining circuits, which are on the chassis assembly, are divided into three sections consisting of a 2-tube signal generator circuit; a 2-tube detector circuit, and associated power supply circuits. Each section will be described in the following paragraphs.

GENERATOR

NOTE: Except for resistance measurements, all bridge measurement functions require the use of a signal generator.

Tubes V1, V2, and their associated circuit components comprise a phase-shift generator having a frequency range of approximately 900 to 1200 Hz. Trimmer capacitor C2 provides a means for setting the frequency to exactly 1 kHz. A portion of the output is coupled back through C2 to maintain the circuit in an oscillating condition. A highly accurate signal source should be used to calibrate the generator.

The 1 kHz output signal is coupled through R7 and C5 to the high side of Generator Level control R8. The 1 kHz signal at lug 2 of R8 is applied to the control grid of V2. The amount of signal applied is determined by the setting of R8. The amplified 1 kHz signal appears at the plate (pin 2) of V2. When the Generator switch is in the AC INT position, this internally generated 1 kHz signal is used for all capacitance and inductance measurements. Inductance and capacitance measurements may be made at a frequency other than 1 kHz by connecting an external generator to the External Generator binding posts and turning the Generator switch to the AC EXT position.

DETECTOR

NOTE: Except for resistance measurements, all bridge measurement functions require the use of a detector.

The detector consists of tubes V3, V4, and their associated circuit components. When the detector switch is in the AC INT position, the built-in detector circuit is used with the panel meter and becomes the null indicator. When the detector switch is in the AC EXT position, an external detector must be connected to the EXT DET binding posts. The null indicator will then be the indicator normally associated with the external detecting device. Note that a detector is used only when a measurement function requires the use of an AC signal, such as for inductance or capacitance measurements.

Set AC ZERO control R18 in series with R19 forms a divider circuit across the 135V DC source of the power supply. Adjustment of R18 will set the meter reading to the desired reference point, normally the 100 μA mark at the left end of the meter scale. Resistor R113 acts as a shunt across the meter.

Tubes V4 and V3 provide a 2-stage amplifier. Until final balance of the bridge, an AC signal will be coupled through C13 to the grid (pin 6) of V4. This signal will be amplified by V4 and V3 and appear at the plate (pin 2) of V3. This amplified signal is coupled through C9 and then rectified by meter rectifier D6 to produce a DC voltage. This DC voltage will now appear at the junction of R17 and R16 where it also is applied to the meter. This voltage is opposite in polarity to the voltage already applied to the meter. The voltage actually applied to the meter will be reduced by an amount equal to the value of the rectified signal voltage, with a resulting decrease in current flow through the meter. This "bucking" voltage will cause the meter pointer to move away from the previously set reference point. Note that the rectified signal voltage will decrease as bridge balance is approached. Therefore, when the bridge is balanced, no "bucking" voltage will be produced and the meter pointer will again read at the 100 μA reference point.

POWER SUPPLY

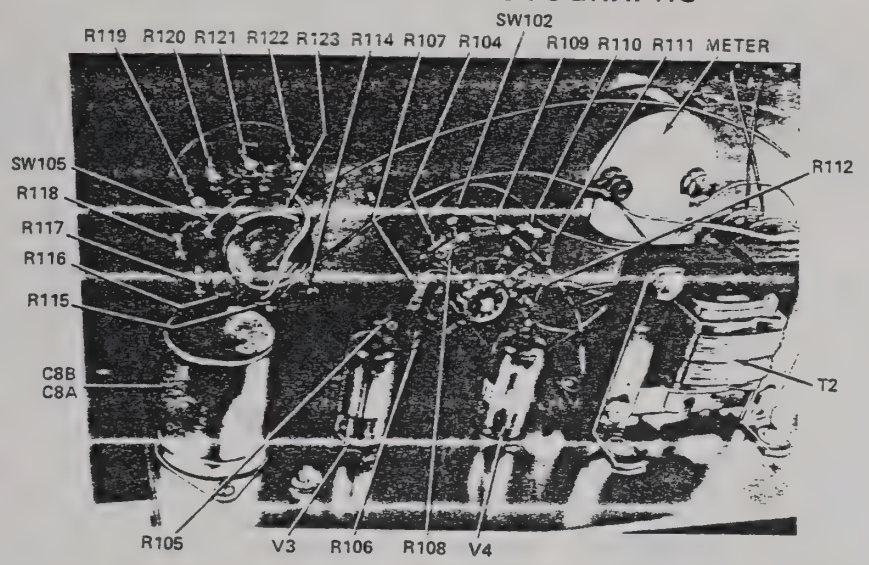
Power transformer T1 has two primary windings that can be connected for operation from a 120 volt or 240 volt 50/60 Hz power source. For 120 volt operation the primary windings are connected in parallel and for 240 volt operation they are connected in series. The primary leads must be connected as shown in the Schematic so proper phase is maintained.

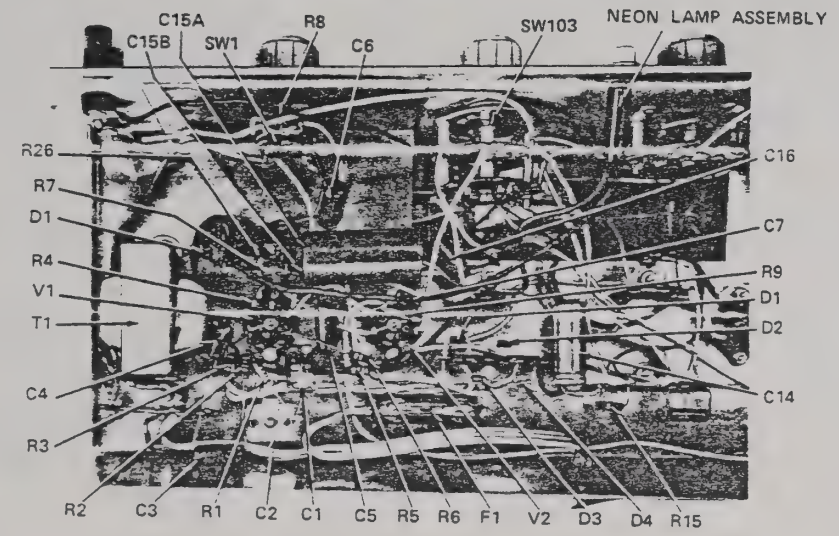
The power transformer has two secondary windings, one for the low voltage supply and one for the high voltage supply.

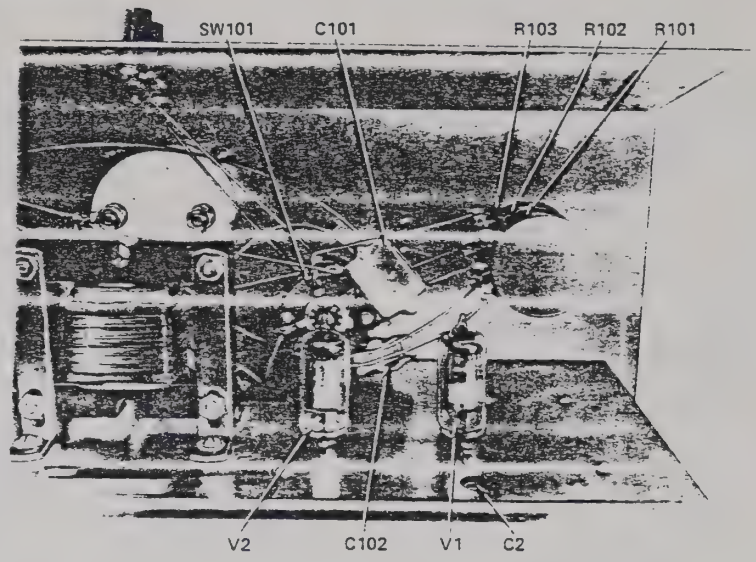
The low voltage supply uses diodes D1, D2, D3, and D4 in a full-wave, bridge-rectifier circuit; and filter capacitor C14 to provide a source of low DC voltage to light the filaments of tubes V1 through V4. With the Generator switch in the AC INT or EXT position, the output of the low voltage supply is applied through lugs 6 and 7 on wafer 1 of the Generator switch to a voltage divider/filter capacitor network consisting of resistors R10, R11, R12, R13, and capacitors C8A and C8B. The 2.5 volts DC at the junction of R10 and R11 is applied as filament voltage between pin 7 of V2 and chassis ground. Since the filament of V1 is in series with the filament of V2, approximately 1.4 volts DC will appear between pins 1 and 7 of tubes V1 and V2. In a like manner the 2.5 volts DC at the junction of R12 and R13 is the filament voltage source for tubes V3 and V4.

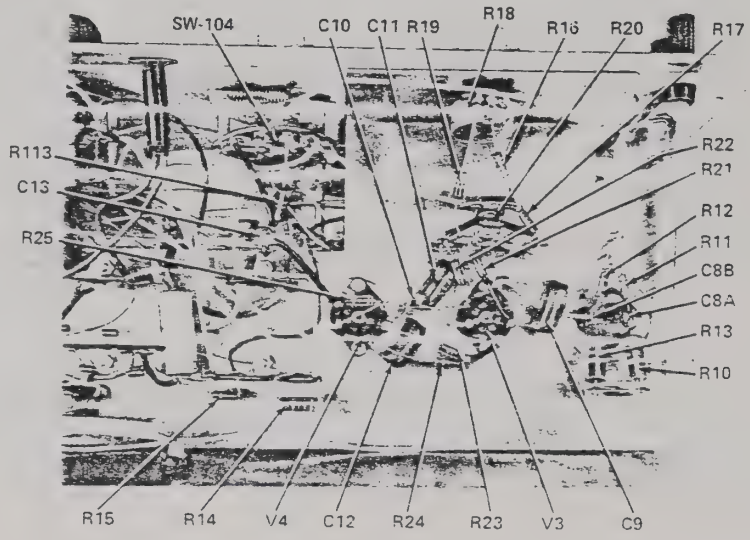
The high voltage supply uses silicon diode D5, capacitor C15A, resistor R26, and capacitor C15B in a half-wave rectifier circuit to provide a source of high voltage of approximately 135 volts DC. With the exception of the tube filament voltages, this supply provides plate, screen, and all other voltages necessary for operation of the Impedance Bridge

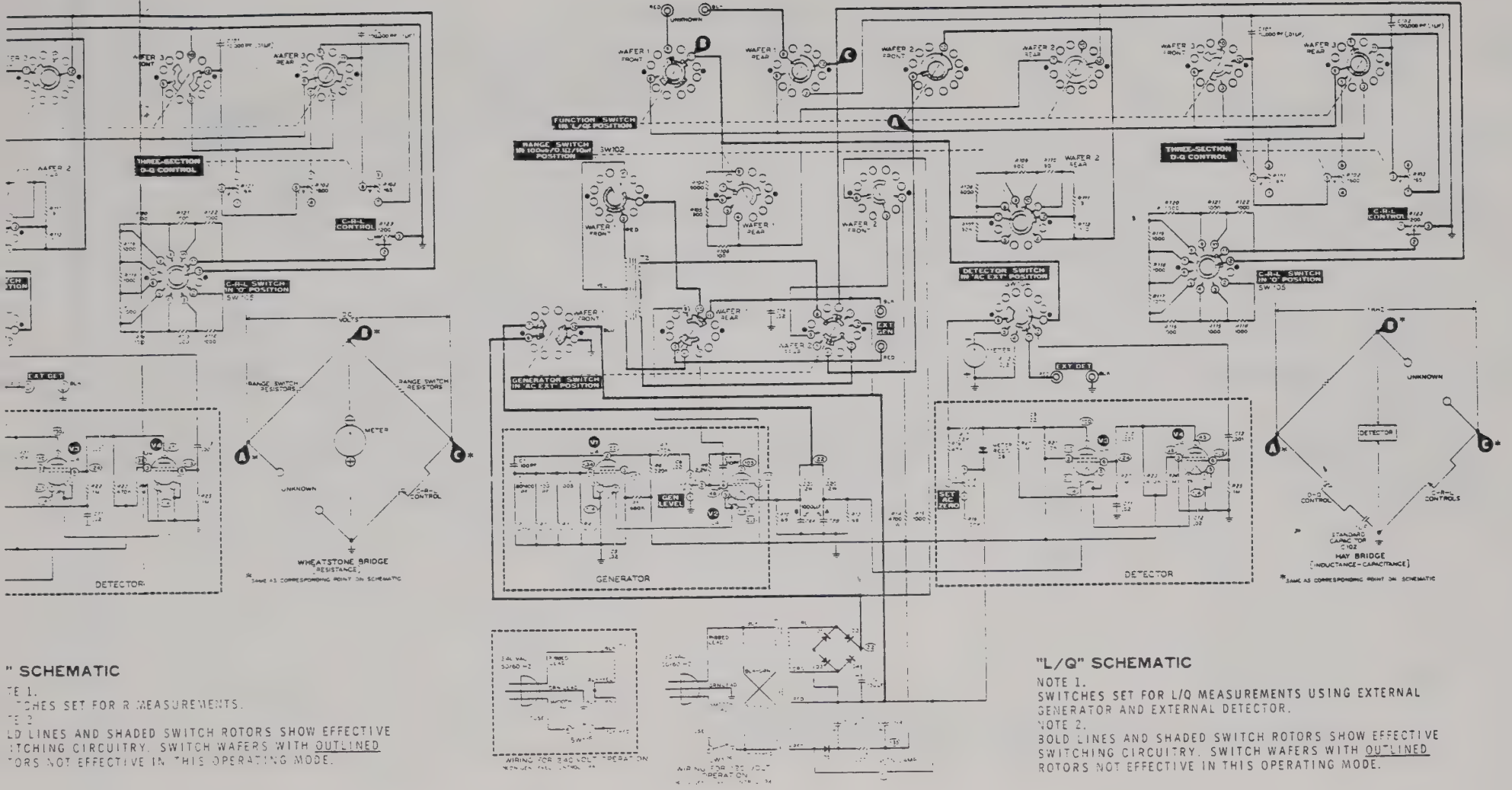
IDENTIFICATION PHOTOGRAPHS









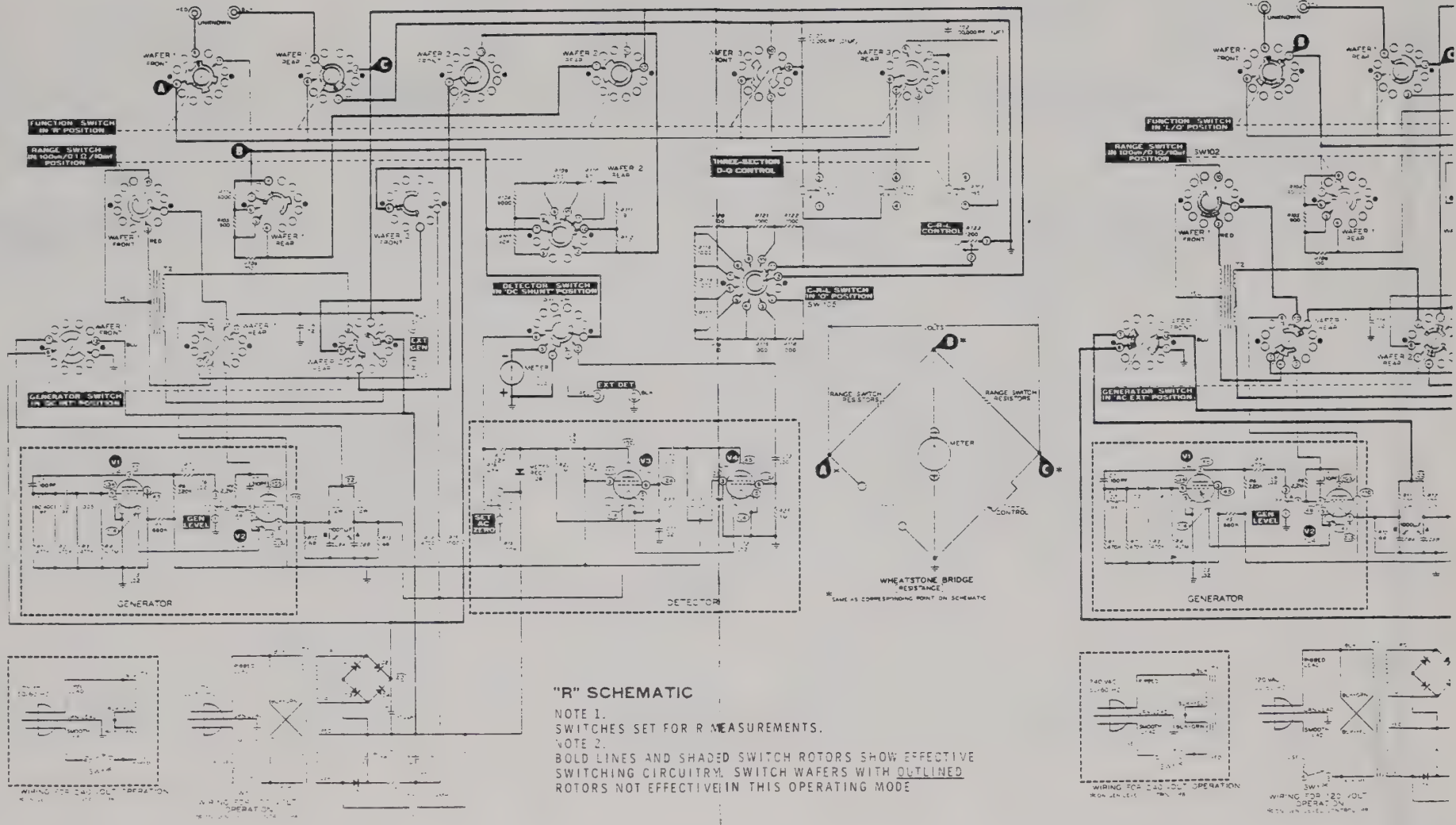


" SCHEMATIC

TE 1.
TCHES SET FOR R MEASUREMENTS.
TE 2
LD LINES AND SHADED SWITCH ROTORS SHOW EFFECTIVE
ITCHING CIRCUITRY. SWITCH WAFERS WITH OUTLINED
TORS NOT EFFECTIVE IN THIS OPERATING MODE.

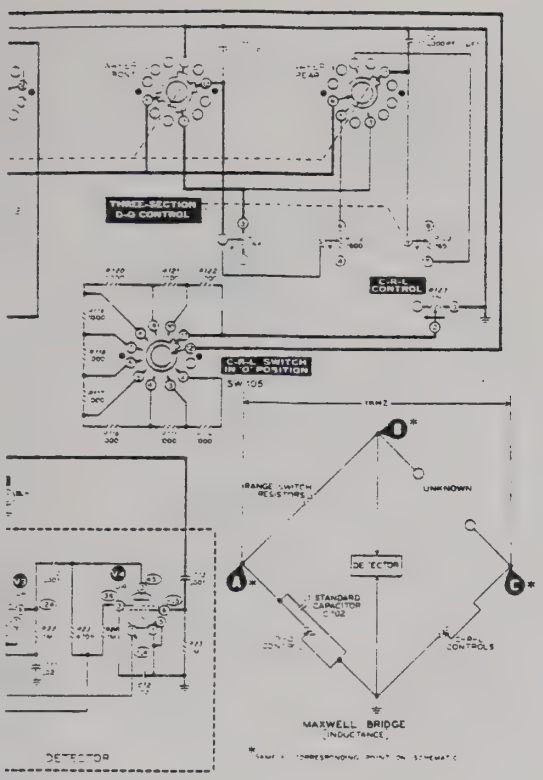
"L/Q" SCHEMATIC

NOTE 1.
SWITCHES SET FOR L/Q MEASUREMENTS USING EXTERNAL GENERATOR AND EXTERNAL DETECTOR.
NOTE 2.
BOLD LINES AND SHADED SWITCH ROTORS SHOW EFFECTIVE SWITCHING CIRCUITRY. SWITCH WAFERS WITH OUTLINED ROTORS NOT EFFECTIVE IN THIS OPERATING MODE.



"R" SCHEMATIC

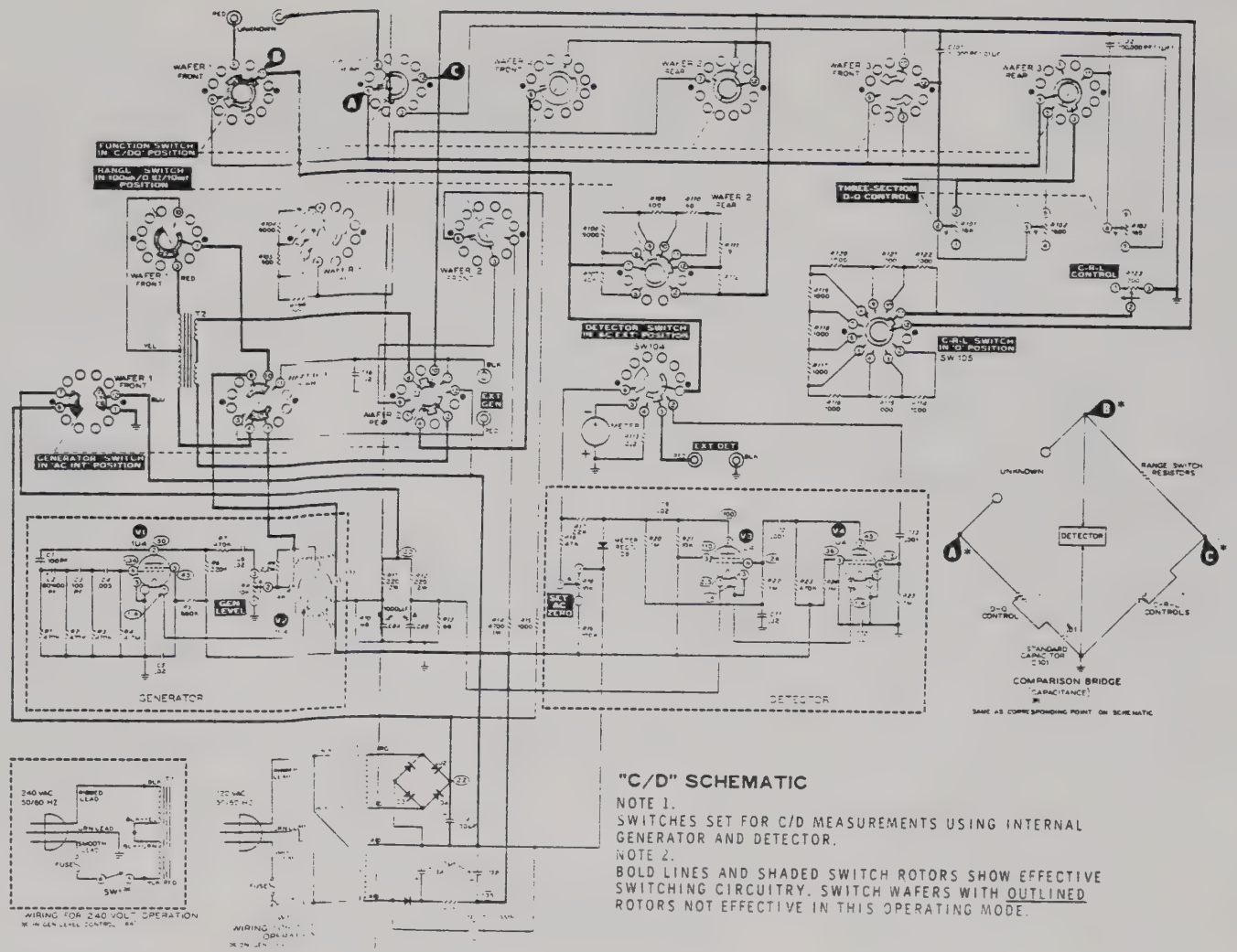
NOTE 1.
SWITCHES SET FOR R MEASUREMENTS.
NOTE 2.
BOLD LINES AND SHADED SWITCH ROTORS SHOW EFFECTIVE SWITCHING CIRCUITRY. SWITCH WAFERS WITH OUTLINED ROTORS NOT EFFECTIVE IN THIS OPERATING MODE



SCHEMATIC

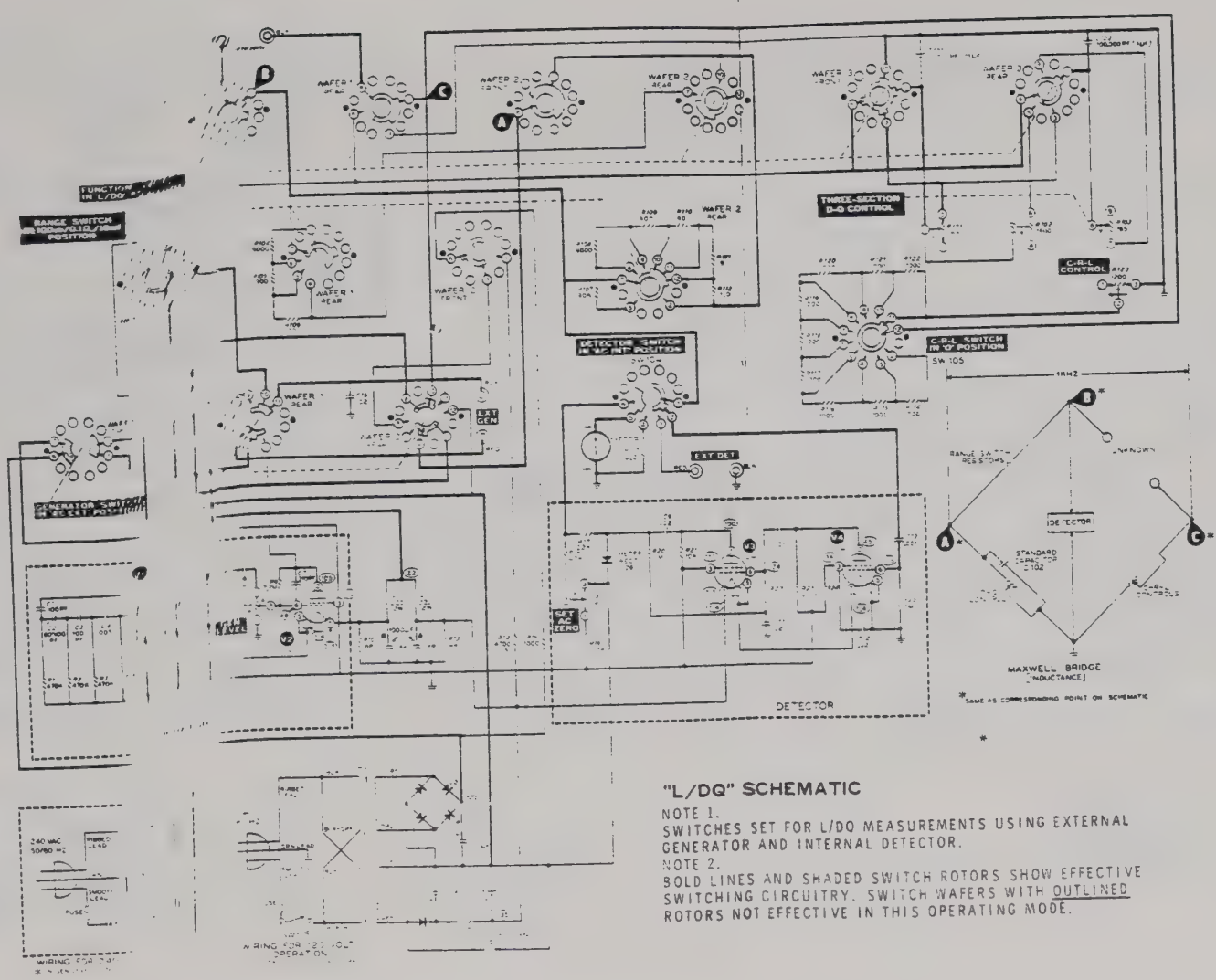
SET FOR L/DQ MEASUREMENTS USING EXTERNAL
R AND INTERNAL DETECTOR.

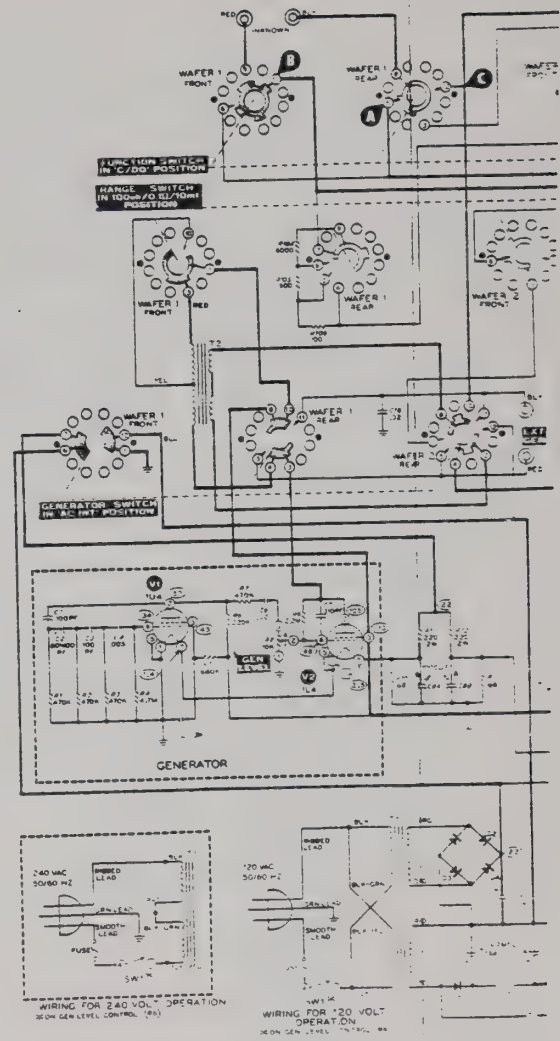
S AND SHADED SWITCH ROTORS SHOW EFFECTIVE
G CIRCUITRY. SWITCH WAFERS WITH OUTLINED
OT EFFECTIVE IN THIS OPERATING MODE.



"C/D" SCHEMATIC

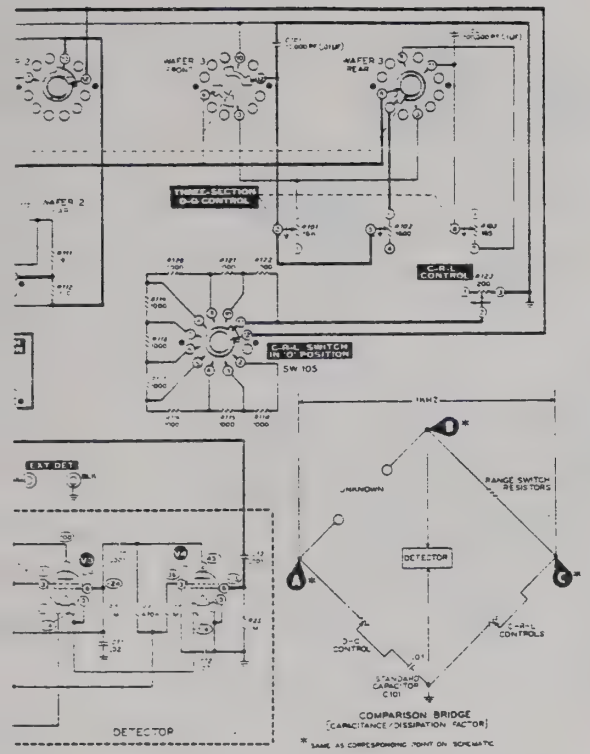
NOTE 1.
SWITCHES SET FOR C/D MEASUREMENTS USING INTERNAL GENERATOR AND DETECTOR.
NOTE 2.
BOLD LINES AND SHADED SWITCH ROTORS SHOW EFFECTIVE SWITCHING CIRCUITRY. SWITCH WAFERS WITH OUTLINED ROTORS NOT EFFECTIVE IN THIS OPERATING MODE.

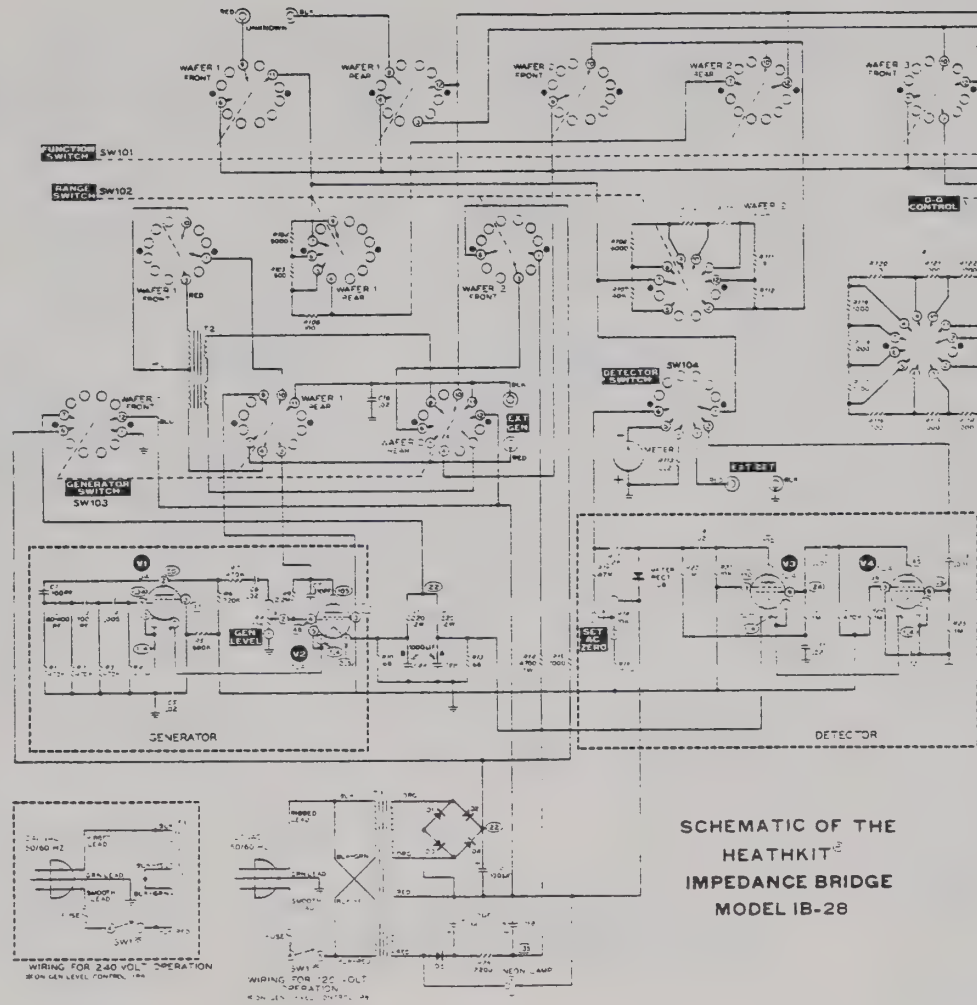




"L/DQ" SCHEMATIC

NOTE 1.
SWITCHES SET FOR L/DQ MEASUREMENTS USING EXTERNAL GENERATOR AND INTERNAL DETECTOR.
NOTE 2.
BOLD LINES AND SHADED SWITCH ROTORS SHOW EFFECTIVE SWITCHING CIRCUITRY. SWITCH WAFERS WITH OUTLINED ROTORS NOT EFFECTIVE IN THIS OPERATING MODE.





"DQ" SCHEMATIC

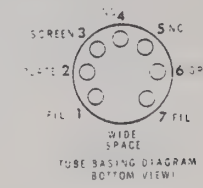
...ITCHES SET FOR C/DQ MEASUREMENTS USING INTERNAL ...ERATOR AND EXTERNAL DETECTOR.

...D LINES AND SHADED SWITCH ROTORS SHOW EFFECTIVE ...TCHING CIRCUITRY. SWITCH WAFERS WITH OUTLINED ...ORS NOT EFFECTIVE IN THIS OPERATING MODE.

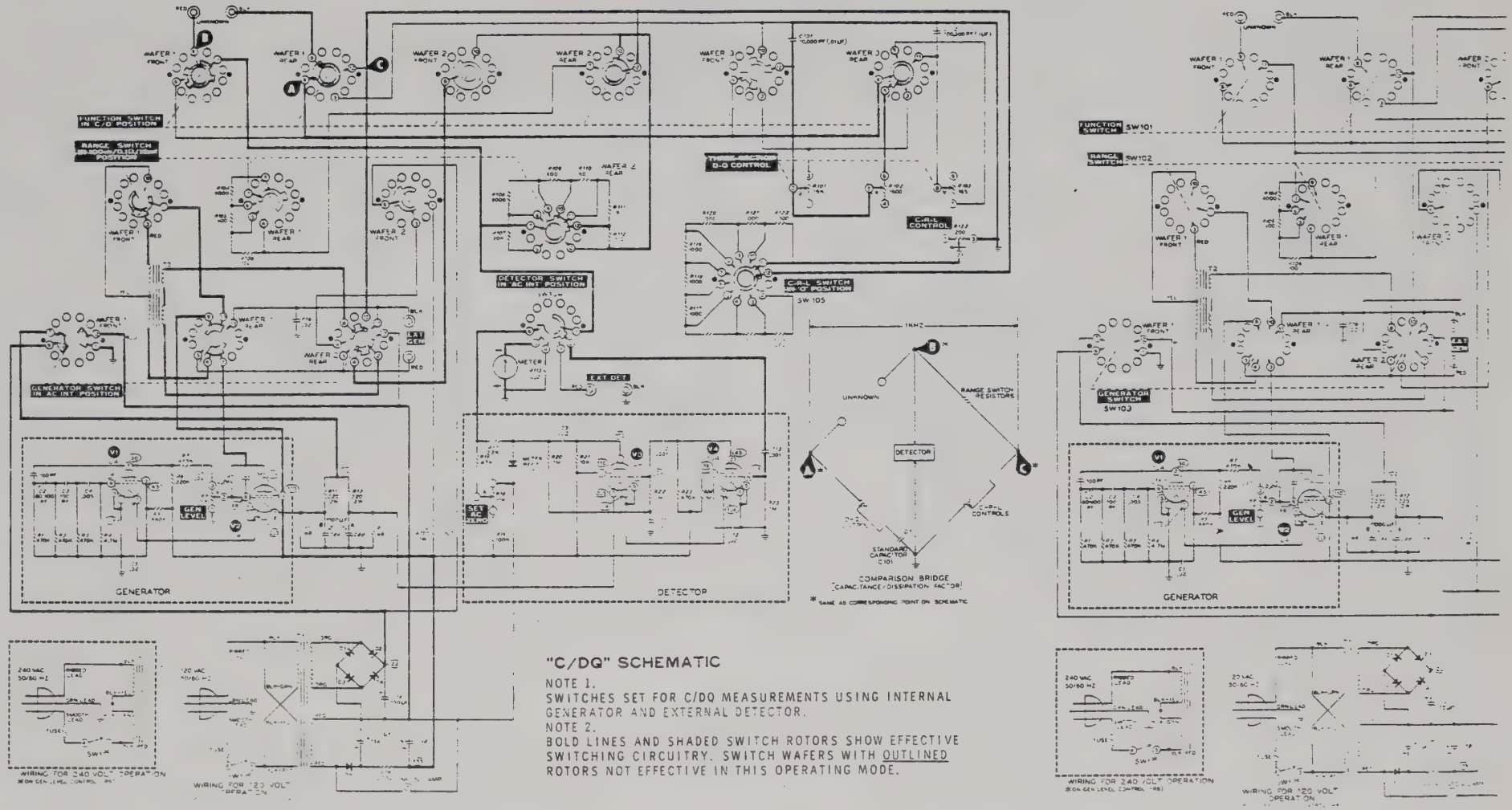
SCHEMATIC OF THE HEATHKIT® IMPEDANCE BRIDGE MODEL IB-28

NOTES:

1. THIS IS BASIC INSTRUMENT SCHEMATIC. FOR SWITCH POSITIONS REFER TO SCHEMATIC FOR SPECIFIC MEASUREMENT FUNCTION TO BE PERFORMED.
2. RESISTORS ARE 1/2 WATT UNLESS MARKED OTHERWISE. RESISTOR VALUES ARE IN OHMS (K=1000 M=1 000 000).
3. CAPACITOR VALUES LESS THAN 1 ARE IN µF. CAPACITOR VALUES 1 OR ABOVE ARE IN pf UNLESS MARKED OTHERWISE.
4. VOLTAGE MEASUREMENTS WERE MADE USING A HIGH INPUT IMPEDANCE VOLTMETER. READINGS WERE OBTAINED WITH THE SWITCHES PRESET AS INDICATED UNDER "VOLTAGE MEASUREMENTS" IN THE MANUAL.
5. TUBE SOCKETS VIEWED FROM BOTTOM OF CHASSIS. LUGS ARE NUMBERED IN CLOCKWISE DIRECTION FROM WIDE SPACE BETWEEN LUGS 1 AND 7.
6. ⬭ THIS SYMBOL INDICATES A DC VOLTAGE MEASURED FROM THE POINT SPECIFIED TO CHASSIS GROUND.
7. ⏚ THIS SYMBOL INDICATES CHASSIS GROUND.
8. COMPONENTS WITHIN DASHED LINES COMPRISE BUILT-IN GENERATOR AND DETECTOR CIRCUITS.
9. COMPONENTS ARE NUMBERED AS FOLLOWS:
   1 - 50 CHASSIS MOUNTED PARTS
   101 - 125 PANEL MOUNTED PARTS
10. ARROWS ON CONTROLS INDICATE CLOCKWISE ROTATION AS VIEWED FROM SHAFT END OF CONTROL.

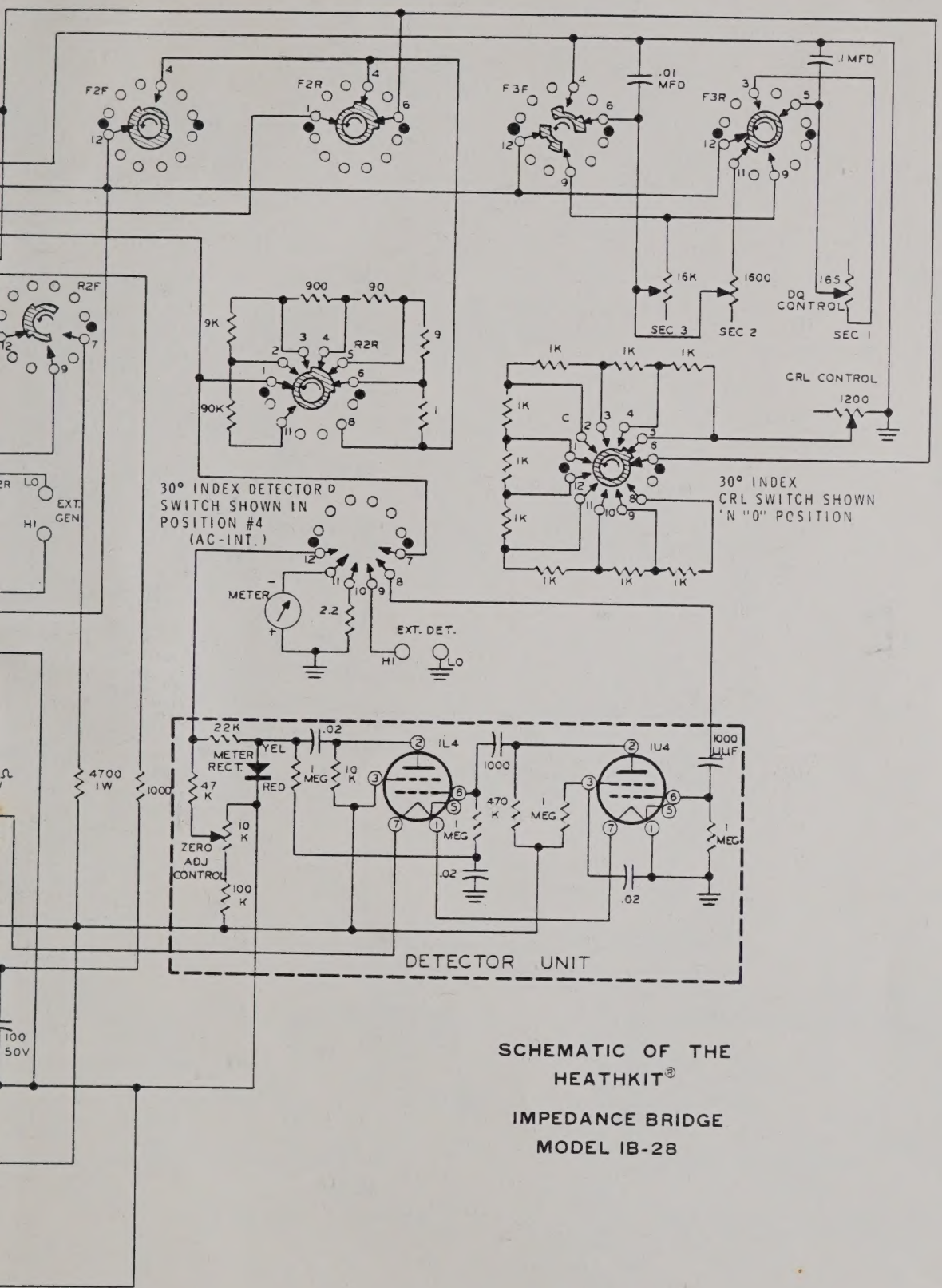


TUBE BASING DIAGRAM (BOTTOM VIEW)

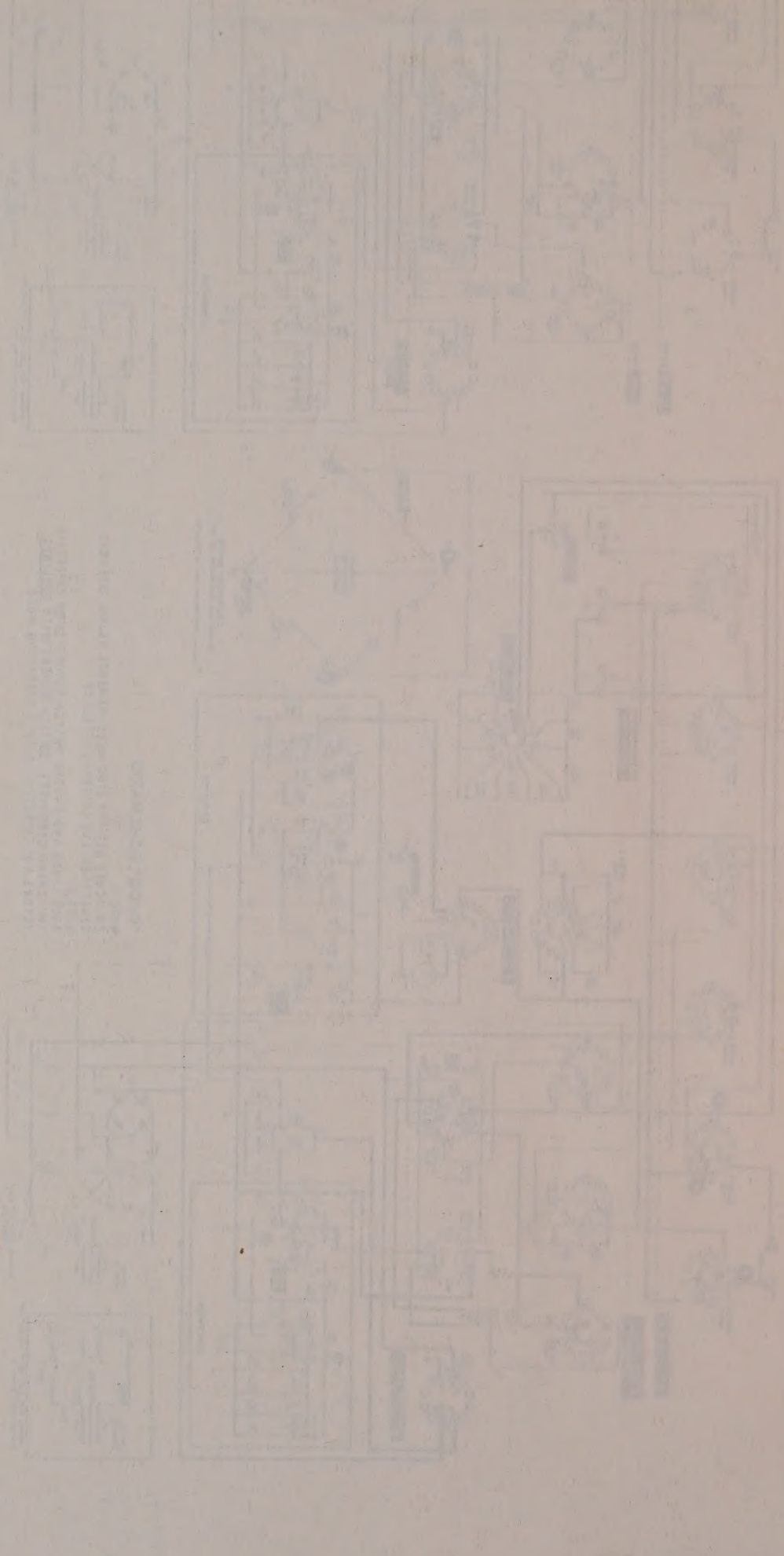


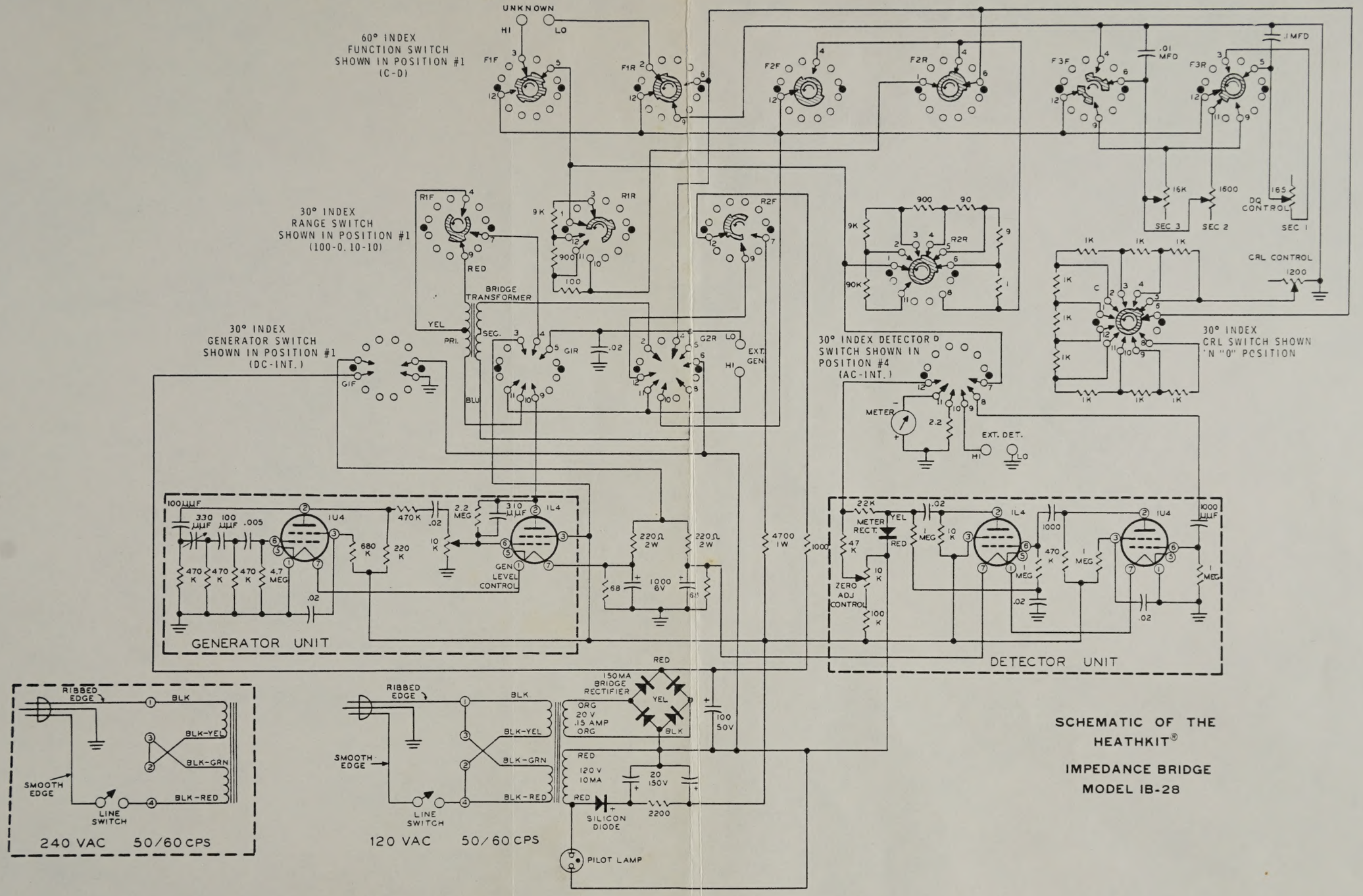
"C/DQ" SCHEMATIC

NOTE 1.
SWITCHES SET FOR C/DQ MEASUREMENTS USING INTERNAL GENERATOR AND EXTERNAL DETECTOR.
NOTE 2.
BOLD LINES AND SHADED SWITCH ROTORS SHOW EFFECTIVE SWITCHING CIRCUITRY. SWITCH WAFERS WITH OUTLINED ROTORS NOT EFFECTIVE IN THIS OPERATING MODE.



SCHEMATIC OF THE
HEATHKIT®
IMPEDANCE BRIDGE
MODEL IB-28





SCHEMATIC OF THE
HEATHKIT®
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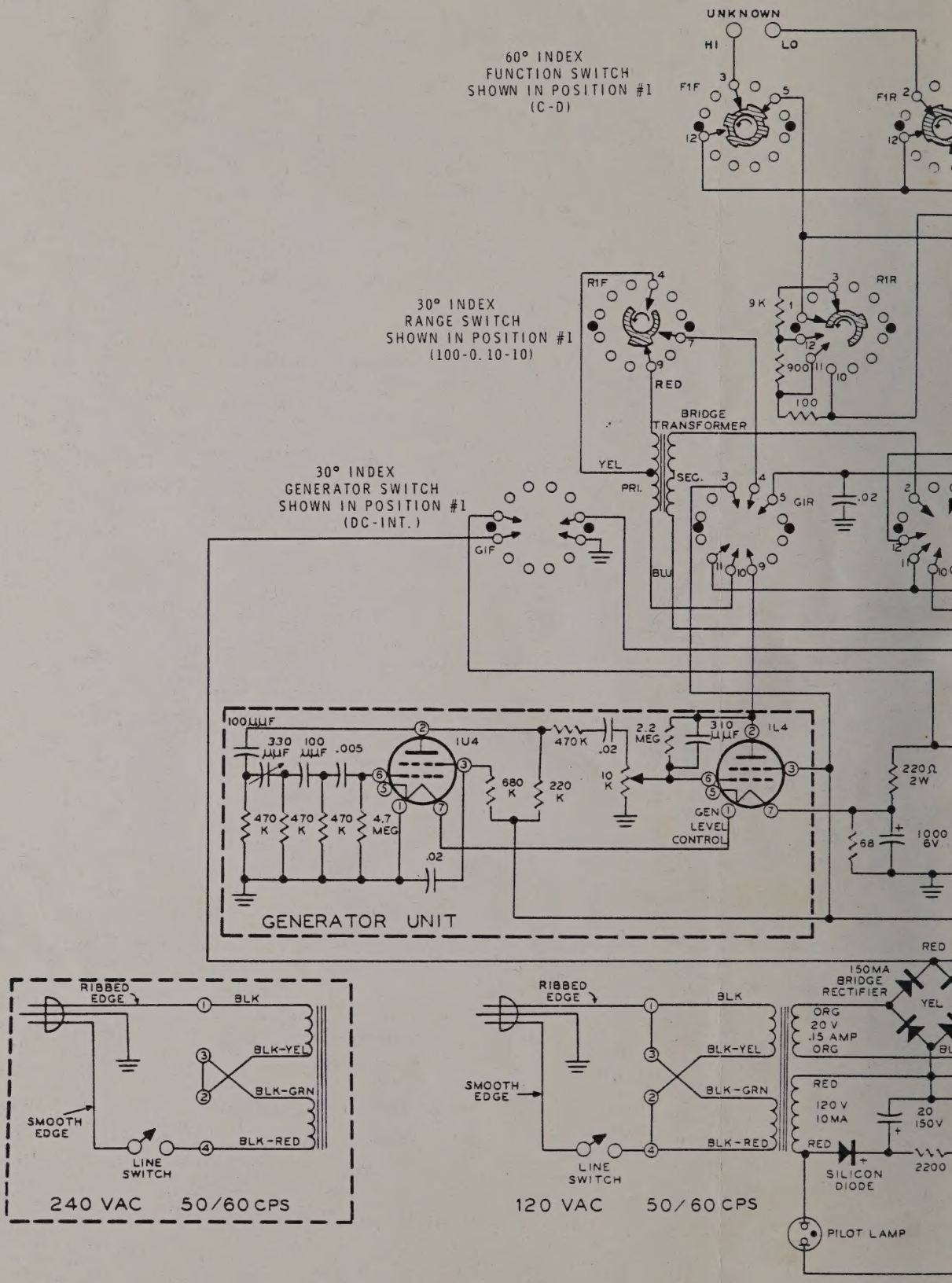
MODEL IB-28


UNKNOWN
HI
LO
60° INDEX
FUNCTION SWITCH
SHOWN IN POSITION #1
(C-D)
F1F
F1R
30° INDEX
RANGE SWITCH
SHOWN IN POSITION #1
(100-0.10-10)
R1F
R1R
9K
900
100
RED
BRIDGE
TRANSFORMER
YEL
PRI.
SEC.
30° INDEX
GENERATOR SWITCH
SHOWN IN POSITION #1
(DC-INT.)
G1F
G1R
BLU
100 μμF
330 μμF
100 μμF
.005
1U4
470 K
.02
2.2 MEG
310 μμF
1L4
680 K
220 K
10 K
470 K
470 K
470 K
4.7 MEG
.02
GEN LEVEL CONTROL
220Ω 2W
68
1000 6V
GENERATOR UNIT
RED
150MA BRIDGE RECTIFIER
YEL
ORG
20 V .15 AMP
ORG
RIBBED EDGE
BLK
BLK-YEL
BLK-GRN
BLK-RED
SMOOTH EDGE
LINE SWITCH
240 VAC 50/60 CPS
RED
120 V 10MA
20 150V
RED
SILICON DIODE
2200
PILOT LAMP
120 VAC 50/60 CPS